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Population Trends and Water Supply

By Charles J. Alfke

IT IS the author's intention in this paper to allude to the trends of population which have been experienced in the United States and, particularly, in the northern metropolitan area of New Jersey, and to bring to the reader's attention the importance of this factor in formulating estimates of future demands on water properties.

The two most important factors involved in effecting changes in the demand for water are the increase or decrease in population and the increase or decrease in industrial consumption. Changes in industrial consumption depend, of course, upon the type of industries in the area and upon whether the area is limited to one or a few types of industry or has a cross-section of all types. A concentration upon one type of industry is apt to result in wide fluctuations in industrial consumption whereas diversified industrial activity will usually result in rather uniform consumption. These are direct effects, but indirectly, too, industry may affect water consumption by the changes in population which result from the growth or recession of industrial activity in any particular area.

The recent 1940 Census shows the population of the United States to be 131,669,275. In 1790, the date of the first census, the total was

A paper presented on February 19, 1941, at the New Jersey Section Meeting, New Brunswick, N. J., by Charles J. Alfke, Manager, Hackensack Water Co., Weehawken, N. J.

only 3,929,214. This is, of course, going back a long way, but it is enlightening to realize that since 1850, percentages of increases by decades have been dropping continually. Percentage increases, however, are not particularly enlightening in regard to the determination of actual consumption data. It is more indicative in such a connection to examine actual numerical increases in population, e.g., population increases by decades, which since 1900 have been as follows:

1901–10—15,977,691
1911–20—13,738,354
1921–30—17,064,426
1931–40— 8,894,229

The Bureau of Census of the Department of Commerce at Washington made the following comment in its press release of December 4, 1940, relative to the final figures of the 1940 census:

"It is clear that if the present trends continue, the United States is faced with a stationary or even declining population in about 30 or 40 years. The slowing down of population growth can be laid to the falling birth rate and to the virtual stoppage of immigration from abroad. During the past decade, all of the increase in population represents the natural increase, the excess of births over deaths. In fact, for the first time in the history of this nation the number of emigrants during an intercensal period was greater than the number of immigrants, during the decade from April 1, 1930 to April 1, 1940. The number of persons who left this country for foreign lands exceeded by 46,518 the number who came to the United States. This is in sharp contrast with immigration trends between 1920 and 1930, when 19 per cent of the population increase of 17,064,426 persons during that decade was attributable to immigration."

The birth rate in the United States has been declining for a century. Births per thousand people in 1875 were 37; in 1912 this figure had dropped to 26 and by 1935 it was down to 17, and it is still falling. The death rate has also been falling but not at a comparable rate. Figures on the decrease in the death rate are 18 per thousand in 1900; 13, in 1920; and 11, in 1934. The National Resources Committee states:

"When true rates are computed to eliminate the temporary effects of variations in age distribution, it is found that the intrinsic reproductive trend is already slightly below that required for permanent population replacement."

No doubt all sorts of conclusions will be drawn from these facts and trends as has been done in the past. As late as in the 1920's some people were predicting a total population of 300,000,000 for the United States.

Students of population today have been able to conclude that populations in cities no longer reproduce themselves and that they must grow, if at all, from population movements. This, of course, is another interesting study, the movement of people from one section of the country to another being brought about almost entirely by the possibilities of financial and cultural advancement. Such movements of population are highly unpredictable, but it is evident that during the last decade there has been a distinct movement away from the larger cities.

TABLE 1

Population Data for the State of New Jersey, 1901-40

PERIOD	BIRTHS	DEATHS	EXCESS OF BIRTHS OVER DEATHS
1901–10	421,793	348,568	73,225
1911–20	678,952	423,770	255,182
1921–30	729,825	420,471	309,354
1931–40	573,396	440,202	133,194
Totals	2,403,966	1,633,011	770,955

Population Trends in New Jersey

In regard to the population trends for the State of New Jersey, Table 1 gives data for the years 1901 through 1940. These figures were taken from data collected by the State's Bureau of Vital Statistics. An examination of the original data will indicate that the birth totals decreased sharply between 1924 and 1940, from 76,530 to 59,328. On the other hand, the death totals for this period increased from 40,531 in 1924 to 45,194 in 1940. In these figures, the year 1924 has been used as a basis of comparison because the birth rate in New Jersey reached its peak at that time and because National Resources Committee reports indicate that the national birth rate also reached its peak during the period from 1921 to 1925.

The comparative census figures for the counties and cities of New Jersey for 1930 and 1940 are very interesting. The low population increase, only 118,831, that is from 4,041,334 to 4,160,165, during

that time was a considerable surprise. An examination of the basic figures indicates that in most of the larger cities and industrial sections population actually decreased during the period, while all of the counties, except Hudson, Cape May and Atlantic, showed an increase. In Hudson County, for which some organizations had predicted an increase, population actually decreased from 690,730 in 1930 to 652,040 in 1940. It is especially interesting to note that a number of the larger cities and industrial municipalities in the State showed similar decreases.

A condition which, no doubt, is common to all plants in the northern metropolitan area of New Jersey, has been experienced by the Hackensack Water Company during the past 40 years. Since 1900, the average number of individuals per meter in service has been declining. Since 1910, in fact, the average number of persons per meter on the system has decreased from 7.8 to 5.4 in 1940.

Fallacy of Predictions

The author is not trying to prognosticate nor is he attempting to draw any conclusions from these facts and trends in population. It is, of course, absolutely impossible to draw any definite conclusions as to the future from such a study of past events. Statistics are constantly being upset as guides to the future. It seems that people are more impressed by, and therefore more subject to, statistics now than at any other time, but this certainly has no effect on reliability notwithstanding Elbert Hubbard's statement: "Let me prepare the statistics and I will prove anything."

No one could have foreseen the invention and complete commercial application of such developments as the telephone, automobile, radio and airplane. As a matter of fact, these inventions, in all cases, were brought into current use over a certain amount of opposition and despite a number of doubters along the way.

Statistics are valuable historically but prognostications must always be made on the basis of a look into the future. Prognosticating the future by prolonging the curve of history is fatal.

Unless something is done to reverse the population trend which is evident from the figures at hand, one of two possible population trends will, according to the National Resources Committee, result, estimates being: a peak of 137,172,000 in 1955, followed by a decline to 127,571,000 in 1980; or a continued rise to a peak of 173,541,000 in 1980.

Effects of Population Trends on Water Works

It is clear that the problem of the water works operator is rapidly changing from one of expansion of the property to one of keeping the property up to modern standards, the present task involving replacements and possibly, in some cases, major rehabilitations.

Water properties in northern New Jersey reached a daily consumption peak in the late 20's and the early 30's. The Hackensack Water Co. system has not exceeded that peak—an experience not uncommon in the northern metropolitan area. In consideration of the information to be gleaned from population curves this condition is to be expected. Today with the success of low-priced housing projects, and the resulting inoccupancy of old houses, the population trends of many localities have been disrupted. The history of the United States and its municipalities is one of frequently changing centers of population.

Statistics show that in 1929 there were approximately 29,000,000 families in the United States while today there are approximately 33,000,000. On the other hand, statistics of school population in the larger cities show a considerable decline.* Space will not permit a discussion of the reasons for such a leveling off of population, but it must be apparent to everyone that it is happening. The varying effects of such a declining and aging population on business make a particularly interesting study which indicates that in the future business will have to cater to older rather than to younger people, and this greater age of the population seems to point to the continuation of increase in the number of families even though total population increases very slowly or not at all. Such a result would, of course, be significant to the water works man from the fact that the increase of families would increase the number of residences required.

There is nothing more interesting and more enlightening to a

* Average day school enrollment in 1932 was 734,445; in 1933, 748,922; in 1939, 693,070; and in 1940, an estimated 680,000.

In an article prepared by the Bergen County Federation of Taxpayers Association, Inc., the following statement is made: "Word comes from New York City that all examinations for teaching licenses in the academic high schools have been cancelled indefinitely and no further tests will be scheduled at present. It has been explained that this has been caused by the sharp drop in secondary school registration. For the last five years no examinations have been given in the elementary grades; in fact, the number one eligible lists contain about 2,800 names, many having been on the list since 1932."

water works operator than a study of the population trends of his territory—a study of the vital statistics and the factors that tend to encourage or discourage industry from coming into a particular area. Such a study makes planning the future of utility facilities much easier. While preconceived notions of future growth may not be borne out, it is certain that a better job, from the standpoint of expansion of facilities, will be accomplished through such a study than through present hit-or-miss methods.

Relative to industry, each executive must draw his own conclusions as they apply to a particular territory. The author, however, should like to point out that, with United States population relatively static, it will be less of a hardship to industry to operate in the smaller remote communities than in large industrial municipalities where costs of every character are apt to be higher.

Discussion by *J. E. Garratt.* * Mr. Alfke presents, concisely, facts and figures regarding population trends and, in his wisdom, draws only very general conclusions without venturing into the field of prediction as to the effect of these trends on water supply problems. Patterning himself after this wise action, the writer will content himself with illustrating the points which have been brought out by actual occurrences in the water supply problems in New Jersey during the last fifteen years, and draw only general conclusions.

Many predictions of future water needs in northern New Jersey were made between 1925 and 1930. Wanaque was being hastened to completion. The Chimney Rock Supply was being promoted. Reports on additional supplies for the City of Elizabeth and for Bergen County were made by the North Jersey District Water Supply Commission. The State Water Policy Commission took up the agitation for additional water. Buddvale, Bunnvale, Vernoy and other developments were proposed. The year 1937 was set as the deadline for completion of an additional supply. With continuing discussion, however, first 1940 and finally 1945 were determined to be the dates when the additional facilities would be absolutely necessary. Even this prediction became questionable though when, after 1930, the effects of the depression on water consumption became evident.

Mr. Alfke points out that industries moved away from the cities; that people moved away and families consolidated their living arrangements; that population figures had not increased according to expectations; that changing water demands in industries caused

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tremendous decreases in the use of water, as illustrated in the changes in gasoline refining processes in Bayonne and silk dyeing processes in Paterson and Passaic. Agitation for new water supply developments, however, continued. While these factors which indicated reduced demands were recognized, there were also factors on the other side of the picture. Air-conditioning was expected to cause heavier demands than could be met by existing facilities, and it was felt necessary to provide reserves against similar uses which might arise to place sudden heavy demands upon the water supply. For these reasons no strong engineering opposition arose. In any event, it seems impossible to determine definitely whether decreases in population, shifting of population and changes in industrial demands for water make it necessary to add to available developed water supplies at any given time.

To the writer this experience indicates that any sound policy of water supply development in the state requires the existence of a state water agency—call it commission, authority or what you will—able and ready to act when and as the need of additional supply is more clearly evident. Such an agency must be fully aware of the many uncertain factors affecting future water supply requirements; must be fully aware of existing surpluses of supply; and must be determined to do its best to utilize completely all existing facilities rather than to impair the financial status of existing water supplies, whether owned by municipality or private company, as at present, or solely held and controlled by one state agency, by building new works before they are actually required and before they can be soundly and economically advanced.

Discussion by *Reeves Newsom*.* In his very interesting and timely paper, Mr. Alfke has denied any purpose to prognosticate as to the future effect of changing population trends because the very changes now taking place prove the danger of projecting curves of the past into the future. The writer believes, however, that it would be interesting to explore the future a little, on the assumption that these changes represent, at least for some time to come, a new set of conditions to which we must adjust our outlook and plans and toward this end he should like to point out some of the things we may expect to occur if the growth of most cities and of our population has substantially ceased.

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The first likely result will be that water works men will have more time to think about the efficiency, economy and effectiveness of their operating and maintenance methods and the quality of the service they are rendering. In many water plants the primary interest of the whole department has been to keep up with growing demands for service in new territories—for more water and for more pressure because of the increased flows required through the older pipe lines. That work has been the gage of activity and the factor which determined the size of the personnel. Every operator knows of a dozen or more things having to do with more efficient operation, better maintenance, more complete records, or improvement in quality of service or the department's public relations, which he has been hoping to get around to for years, but too much time and thought has had to be given to the problems resulting from the growth of population. It may safely be predicted, then, that improvement in all phases of quality of service as distinct from quantity of production will be one result of the cessation of growth in population.

The demands arising from the present defense activities will, in many places, postpone the effects of the general population situation, but since we are discussing the matter as it will influence the next term of years, say a decade or longer, such demands are not pertinent to the subject.

A second factor involved in the situation will be that nearly all facilities will last longer. Sources of supply that have seemed to be nearing their safe limits will be found to be adequate for a surprising number of additional years, judged by past standards. Transmission lines and main distribution feeders will not have to be reinforced as soon as anticipated. Purification and pumping plants will continue to serve, without the enlargements that were expected would be necessary. To be sure, the modernizing of these types of equipment to furnish conditioned water and to produce required pressures with smaller power bills may be expected to proceed more rapidly because such improvements are among the things that have to wait while growth is the main purpose, but modern plants, where only size is in question, will not have to be changed for a while and that future step in the development of a plant to its ultimate planned size will not have to be taken as soon as was expected.

Many of the elements of a water plant are fundamentally long-lived. In the past much of such physical life could not be realized because changes from rapid population growth made it necessary to replace

many facilities which were inadequate, although substantially as capable of doing the job they were designed for as on the day they were put in. It is, of course, also true that, as experience has accumulated, materials and equipment have been better made, mechanical facilities have been nearer the highest practical efficiencies attainable, mixtures of metals have become more resistant to destruction, and methods of preventing corrosion and other forms of deterioration have been invented and put into practice. All these modern factors help to prolong the life of water property, but, in spite of them, changes from rapid growth and population movement would necessitate considerable replacements. With that influence on the wane, however, fuller advantage can be taken of the progress made in perfecting water works materials and equipment. This will mean that less depreciation will occur in water plants in the future, and in turn, that the term of municipal water works bonds can justifiably be lengthened, or that provisions for depreciation in any form can be less of a burden to the rate payer.

Cessation of population growth does not mean that population movement will cease. The experience in American cities which have already been stationary in growth for a quarter of a century or more shows that at periodic intervals there is a tendency on the part of the inhabitants of a community to "move out farther" or to "move back into the middle of things." As peoples' fortunes change there are regroupings of home owners in new areas and abandonment of older sections of the city to cheap housing or business. This, it is supposed, will continue, so that, to that extent, there will always be extensions of the distribution system, in all its elements, into new territory and the rendering of some facilities unnecessary or unsuited to the changed type of service; but such relatively minor changes cannot require the major attention of water works men that construction to keep up with the rapid growth of the past has demanded.

With more time to devote to the problem of operation, the percentage of water accounted for should generally rise. This is a function of the frequency and thoroughness of underground wastage elimination work and the quality and frequency of meter repairs, both of which have to suffer when construction of new facilities is foremost in the minds of a department's personnel.

One thing that will need to be watched more carefully than in the past is the making of main extensions for housing developments. The private companies in New Jersey have a substantial measure of

protection in the methods of payment or guarantee required by the Public Utility Commission; but the municipal operator is subject to the pressure to create new taxable property by extending water mains first, the building of houses to follow. In the future a smaller percentage of such projects will work out to be paying propositions for the water works and they will have to be undertaken less readily than when population growth could be counted upon to fill in the gaps in a few years.

Summarizing these thoughts, the writer should expect that, as a result of the population trends shown in recent years, the water works industry is approaching a period when it will get a chance to do the hundred and one things on the operating end which it has never had time to get around to. As a result, service, in the broadest sense of the word, should become better, and, ultimately, the cost of the improved, though more efficient, service should be less. At the same time, it will be found that cessation of growth in population, combined with the progress in improving the resistance of materials and the efficiencies of mechanical facilities, will result in maintaining the adequacy and effectiveness of nearly all elements of a water works system, from the source of supply to the machines for making the bills, for longer periods than in the past or than had been anticipated for the future.

Centrifugal Pump Performance

By John Burgess

AN EASY way to dismiss the subject of pump performance is to say: "You push the button and we do the rest." If one were to observe some pump station operators this would seem to be all that was necessary. The operators do have to put new oil in the pumps about once a month, they may have to make an oil change once a year and occasionally put additional packing in the pumps, but that is about the total of their attention to the equipment. In a machine with but one moving part there is not much to get out of order. Frequently, it is not even necessary to push a button, for in a great many automatic stations there have been installed centrifugal pumps which require no attention excepting an occasional checkup to see if everything is running smoothly. To obtain such performance from the pumps, considerable thought must, of course, be given to the installation beforehand. A centrifugal pump, like most engineering equipment, is a very efficient and trouble-free piece of machinery if it is used under the conditions for which it was designed, but it may give no end of trouble if put to uses for which it is not suited.

Some of the characteristics of centrifugal pumps are as follows:

1. They can attain efficiencies of over 90 per cent. These efficiencies will vary according to the size of the pump, the smaller sizes, in general, being less efficient than the larger ones.

2. They can be made to pump to almost any desired pressure by their use in series or in multiple stages. Pressures up to 2,000 lb. per sq.in. are in common use.

3. They can deliver water in almost any desired quantity—from the small amounts handled by a circulating pump on an automobile

A paper presented on September 17, 1940, at the Rocky Mountain Section Meeting, Denver, Colo., by John Burgess, Office Engineer, Board of Water Commissioners, Denver, Colo.

radiator to the quantities delivered by storm sewer water pumps, at rates up to 100,000 g.p.m.

4. They will pump any liquid that will flow. Pump catalogues list, among other things, pumps for molten lead, sewage and gasoline.

5. They can be connected to almost any type of prime mover, electric motors, gasoline motors, diesel engines and steam turbines being the most common types of drive.

6. They can be made to operate at varying speeds and still maintain their high efficiency; but it must be remembered that capacity will vary directly with the speed, head will vary as the square of the speed and the power required will vary as the cube of the speed. If, then, the speed is increased 10 per cent, 10 per cent more water will be delivered at 21 per cent more head and the power bill will be 33 per cent more. This is true, however, only if use can be made of the additional head created. If an effort is made to increase the output by increasing the speed and, at the same time to maintain the original head, decreased efficiency will result.

7. Their cost of installation is many times less than that of steam units of equal efficiency. In one case it was estimated that for an output capacity of 40 m.g.d. in steam equipment the cost would be $6,175 per m.g.d., while motor-driven centrifugal pumps of the same capacity could be installed for $417 per m.g.d.

In addition to these capabilities of centrifugal pumps, certain other facts, concerning the things which they *cannot* perform should also be pointed out, as follows:

1. They cannot prime themselves, advertisements to the contrary notwithstanding. Such pumps when advertised as self-priming are equipped with some type of auxiliary device which must be operated before the pump will start.

2. They cannot use as high a suction lift as a plunger pump, nor operate with air leaks in the suction pipe. With water temperature at 70°F., a 12-foot lift is all that is recommended at the elevation of Denver, and from this amount must be subtracted all the friction losses in the pipe between the source of supply and the nozzle of the pump. If higher lifts are used, the pump may still deliver water but there is grave danger of cavitation in the pump, with consequent rapid losses of efficiency.

3. They cannot maintain high efficiency except for a narrow range near the point for which their efficiency is designed.

4. They cannot exceed designed head except by increasing speed.

In many types of prime movers this is difficult or impossible to do and, even if the head is changed by altering speeds, other undesirable factors are introduced.

5. They cannot maintain high efficiencies with gritty water.

Considerations in Judging Performance

In discussing the performance of centrifugal pumps, the date of manufacture has much to do with the question. Performance increased remarkably in the decade 1920–30. Text books prepared some years ago gave little space to centrifugal pumps, and books, published as recently as 1925, stated that their efficiency is not equal to the efficiency of steam pumps. Specifications prepared by the Denver Water Department in about 1925 limited the speed of a 5-m.g.d. pump to 1,200 r.p.m., because it was feared that higher rates would set up excessive vibration. At present, 1,800 r.p.m. is not considered excessive speed for a pump of the same capacity. In some small sizes, in fact, pumps of 6,000 r.p.m. are now being manufactured.

Early text books stated that, for best efficiency, the lift in the single stage should not be over 100 ft. On the Colorado River Aqueduct, pumps of about 130 m.g.d. are pumping a head of 450 ft. in a single stage, and lifts up to 700 ft. have been built. The best speed, height of lift, etc., will, of course, vary with the size of the pump.

Water works men are interested mainly in three different types of pumps, i.e. trench pumps, well pumps, and booster pumps for distributing water under heads that are higher than obtainable by gravity flow.

Centrifugal pumps provide very light and convenient trench pumps. The Denver Water Department, for instance, finds a 2-inch size, direct-connected to a gasoline motor, suitable for the majority of its requirements. Such pumps are made by two or three different manufacturers.

The size, lift and capacity of well pumps are determined by the characteristics of the well. For a number of years the standard well pump has been of the turbine type set below the water level of the well, but driven by a motor at the surface, connected by a long shaft with bearings at frequent intervals. At present there is available a submersible motor by which such pumps can be driven without the use of the long shaft, thus effecting a considerable saving in the amount of power required to pump the water.

In connection with the statement made previously that a pump cannot maintain its efficiency with gritty water, it was interesting to note in one case, after a well had been sunk, that an old pump was used for several months until the well had been cleared of sand before the final installation of highly efficient pumps was made. The expectation was that the efficiency of the new pumps would in this manner be maintained without difficulty in the clear water.

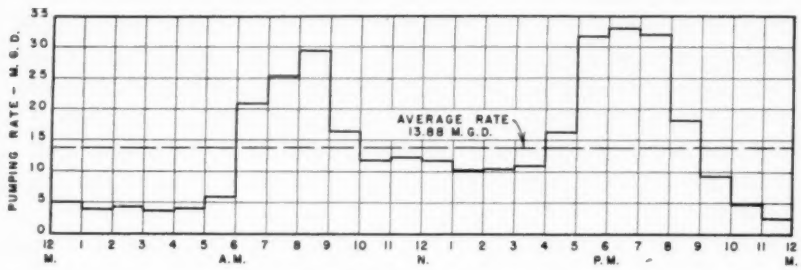

FIG. 1. Hourly Pumping Rates for a Typical Day

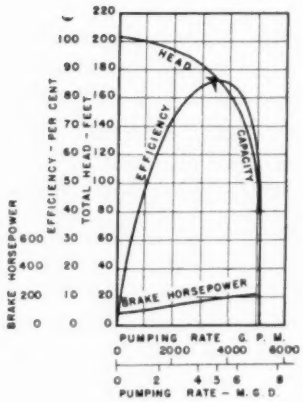

FIG. 2

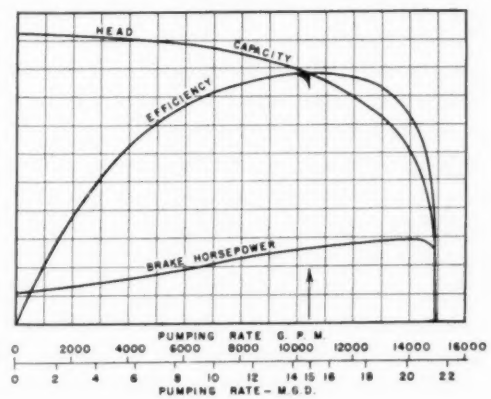

FIG. 3

FIG. 2. Typical Performance Data for 5-m.g.d. Centrifugal Pump
FIG. 3. Typical Performance Data for 15-m.g.d. Centrifugal Pump

Determination of Capacity Requirements

As a rule, further factors must be taken into consideration in the selection of pumps for delivering water into a city distributing system. The fact that the capacity cannot be varied greatly without impairing the efficiency makes it necessary to study the type of load to be car-

ried, whether it be a continuous load of constant amount or an intermittent load with varying quantities. Load curves should be carefully studied to make possible the selection of proper sizes.

In Figs. 1, 2 and 3 are given an hourly load curve, taken from one of the Denver pumping stations, and two typical performance curves of centrifugal pumps of 5-m.g.d. and 15-m.g.d. capacity. On the load curve (Fig. 1) it will be noted that the peak rate of pumping, 33 m.g.d., is more than double the average rate, about 14 m.g.d., and more than ten times the minimum rate, $2\frac{1}{2}$ m.g.d. By making no allowance for future growth it might have been possible to take care of this load with two 15-m.g.d. pumps and, while pumping at full load, to maintain an efficiency of 88 per cent with a required lift of 176 ft. It will be noted that, during the middle of the day, there were five or six hours when the load was but 10 m.g.d. At this rate of pumping the efficiency of the pump would drop to about 81 per cent and the head would be increased to 194 ft., requiring 420 b.h.p. With a 10-m.g.d. pump available, the same load at the desired head could be taken care of with 350 b.h.p., or at a 16 per cent saving in power. When the night load of less than 5 m.g.d. is considered, the large unit is demonstrated to be even less efficient. Under these conditions it would pump to a head of 202 ft. with an efficiency of 58 per cent and require about 300 b.h.p., whereas a 5-m.g.d. pump would not give the excessive head and would pump the desired amount of water using only 180 b.h.p., or at a saving of 40 per cent. Thus, it becomes apparent that it is desirable to install a number of units of varying capacities to take care of fluctuating loads.

While the cost per unit of installed capacity is a little higher in the smaller sizes, the additional cost is much more than made up for in operating efficiencies. The best solution for each individual problem can best be determined after careful study of all the factors entering into the problem. In the particular station described above there is at present installed one $3\frac{1}{2}$-m.g.d., one 5-m.g.d., one 8-m.g.d. and one 15-m.g.d. pumps, all of which make possible combinations which will be efficient for almost any load.

Other Factors in Specification

After a decision concerning the sizes or capacities of the pumps to be installed has been made, there are still a number of other details, which may affect the convenience of the operation of the pump station, for which provision must be made. Probably the most im-

portant of these is the type of driving units for the pumps. This matter, however, is beyond the scope of the present discussion, the only remark to be made being that, for best operating efficiency, the unit should be of fairly constant speed. In ordering pumps, the type of prime mover together with all other necessary data should be specified and understanding should be had as to whether the pump contractor is to provide the unit or whether it is to be provided under separate contract.

For convenience in station design, location of suction and discharge nozzles should also be specified, the common practice being to have horizontal nozzles on either side of the pump. Frequently, however, a bottom suction permits a neater design. The usual pump for water works practice is one with a horizontal shaft, but pumps with vertical shafts are available and may be used under special conditions. It is the usual practice, too, in horizontal pumps to require double suction on the impeller, thus balancing the thrust and allowing the use of more simple thrust bearings. In multiple stage pumps single suction is sometimes used, alternating the direction of flow and thus balancing the thrust.

There are a number of construction details concerning which there may be discussion between manufacturers of different pumps as to the relative advantage of their particular design. The author is inclined to judge a pump on its guaranteed and tested efficiency rather than on these details; and in his experience with the pumps of several different manufacturers, he has had very little trouble with any of them.

Operation at Reduced Capacity

Occasionally a pump must be operated at capacities and heads considerably less than that for which it is designed. The usual practice in Denver, in such a case is to throttle the discharge valve to obtain the amount of water at the pressure desired. As stated previously, this is an inefficient but sometimes necessary method. Another and more efficient method, insofar as the pump alone is concerned, of obtaining the same results is to reduce the speed of the pump. With the usual electric motor drive, however, variable speed may be more expensive than throttling.

Noises and vibration in pumps are usually caused by entrained air, or by too great a suction lift. Elbows too close to the suction end of the pipe may also give trouble. As these conditions are very difficult

to change after installation, care should be taken to avoid them in planning the pumping station.

A centrifugal pump is an open piece of machinery, so, if it stops, water will run backward through it. It is necessary, therefore, in most pumping installations to provide a check valve somewhere in the line to prevent such backward flow. If there is a suction lift, a foot valve will maintain the prime of the pump, but will also increase the lift. Where there is a suction head it is standard practice to put the check valve on the discharge side of the pump. In any case, the valve should be kept in first class condition to be sure or prompt and positive closure. Excessive water hammer may also develop if the check valve does not work properly. At present, however, there are on the market various check valves, specially designed to eliminate this difficulty. In addition to the check valve, gate valves which will allow repairs to the pump with pressure on the system should also be provided.

Electric Power for Water Pumping Plants

By F. I. Fairman

AMONG the many desirable features of electricity as a power source for water pumping plants are its dependability and flexibility. These two features are constantly being improved by the electric utilities which are making available duplicate and sometimes triplicate sources of power by the development of transmission networks with interconnected generating stations. With these advances added to the adaptability, the cleanliness, the ease of application and control, and the economy of electric power, we find many pumping plants being modernized for more effective use of such power. Some examples of such experiences in Kentucky will serve to illustrate the general practice.

For instance, to replace a steam plant which had been in operation for many years, the City of Richmond, Ky., in 1938, built a new electric-powered pumping plant. The pumpage of the new plant is about 1 m.g.d. at a total head of 320 ft., requiring 1.44 kw.hr. per 1,000 gal. pumped.

An automatic pumping and filter plant owned and operated by the Kentucky Utilities Co. at Greenville, Ky., is another example of the use of electric power. The water supply is from impounded lakes, the one adjacent to the pumping station being above that of the low lift pumps. The station's average output is $3\frac{1}{2}$ mil.gal. per month against a pumping head of 215 ft., requiring 2.98 kw.hr. per 1,000 gal. pumped. The high power consumption per 1,000 gal. is due to the pumpage of water from the lower lake to the lake near the pump station during a large portion of the year.

Until 1939 the pumping plant at Cynthiana, Ky., was steam operated. Two motor-operated high lift service pumps and one motor-

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operated fire pump are now located in less space than were the two former reciprocating steam pumps. The average output of this station is ½ m.g.d. against a total head of 258 ft., consuming 1.28 kw.hr. per 1,000 gal. delivered for both high and low lift pumping.

Some data have been assembled from several pumping operations in Kentucky to show how the power requirements vary. It may well be borne in mind that the efficiency of the pumping equipment, as well as the total head and type of pumping, affects the power requirement. No attempt has been made to show the power cost per 1,000 gal.; with the kilowatt hours consumed per 1,000 gal. and the average number of gallons given, however, it is easy to apply the

TABLE 1

Power Consumption of Kentucky Water Pumping Plants

LOCATION	1,000 GAL. PUMPED PER MONTH	KW. HR. PER 1,000 GAL.	TOTAL HEAD IN FEET	TYPE OF PUMPING
Glasgow	6,888	1.59	340	High and low lift
Harrodsburg	4,334	1.52	240	" " " "
Clinton	1,846	4.43	235	Air lift and high lift
Middlesboro	18,552	1.15	230	High lift only
Richmond	22,328	1.44	320	High and low lift
Cynthiana	14,250	1.28	258	" " " "
Danville	22,600	2.28	461	" " " "
Hickman	3,649	2.81	252	Well and high lift
Shelbyville	7,662	1.74	296	High and low lift
Carrollton	3,200	4.56	340	Well, high lift, air lift
Mt. Sterling	7,804	3.15	540	High and low lift
Greenville	3,477	2.98	215	" " " "
Lawrenceburg	7,414	1.47	323	" " " "

rate that may be applicable to determine the power cost per 1,000 gal. pumped. Table 1 illustrates the variation in power requirements with different types of operations.

The two locations that have air lift pumping from wells show a much higher consumption for a given volume of pumping than those locations with a similar total head but which use centrifugal pumps for both high and low lift pumping.

Possibly the better way of showing the effect of system efficiencies on the power costs is to give a few illustrations of actual conditions found in systems and the effect of improvement in the system efficiencies.

One town was operating a pumping plant with low lift pumping from a lake formed by damming a river, and high lift pumping from the clear well into an elevated storage tank. The total head on the low lift pump was 25 ft. at 230 g.p.m. and the high lift head was 227 ft. with 230 g.p.m. Consumption was 2.06 kw.hr. per 1,000 gal. pumped, costing the city $1,821 per year. A test was conducted on the pumps to determine whether anything could be done, with a justifiable investment, to reduce the pumping cost. This test showed that the low lift pump had an efficiency of 40 per cent. A new pump operating under the same conditions would require 2.75 b.h.p. and have an efficiency of 68 per cent. The high lift pump was found to have an efficiency of 43 per cent. A new pump operating under the same conditions would require 26.7 b.h.p. and have an efficiency of 89.5 per cent. With the improved efficiencies of the two pumps, the power consumption per 1,000 gal. was 1.52 kw.hr., or 0.54 kw.hr. (26 per cent) less than the existing pumps. On this basis the operating cost would be $1,345 per year for power, or a saving of $476. This saving was enough to amortize the investment for the new pumps and their installation in approximately 23 months. The change was made and the results proved the accuracy of the tests and savings estimated.

In the above case the only changes necessary were the installation of new pumps and motors. In another case a change in the pumping equipment and the transmission system was necessary to obtain more delivered water and was justified by the savings in power cost. The pumping plant was located about 4 mi. from the elevated storage tank. The pipe transmission line was 6-inch cast-iron pipe with a booster pumping station about 1½ mi. from the elevated storage tank. This booster station was installed in an endeavor to increase the volume of water delivered.

The water supply was from a small river having an elevation about 200 ft. lower than the top of the elevated tank. The total pumping head was 361 ft. with 194 g.p.m. and 422 ft. with 232 g.p.m.

A test was made on the high and low lift pumps, the booster pump, the station totalizing meter and the pipe transmission line. The small high lift pump was designed to deliver 250 g.p.m. at 330 ft. with 68 per cent efficiency; but, actually, it delivered 194 g.p.m. at 326 ft. with 52.8 per cent efficiency. The large high lift pump was designed to deliver 375 g.p.m. at 388 ft. with 72 per cent efficiency, and actually delivered 232 g.p.m. at 387 ft. with 52.4 per cent efficiency. The low lift pumps were operated with throttled discharge,

under which condition the regulation was so difficult that there was almost a continuous overflow from the settling basins. Operating under this condition the consumption per 1,000 gal. was 0.418 kw.hr. for 35 ft. of head. The booster pump increased the flow on the small high lift pump from 194 to 267 g.p.m. and from 235 to 274 g.p.m. on the large high lift pump. The power requirements per 1,000 gal. showed increases of from 15 to 20 per cent when the booster pump was in operation.

A test of the station meter showed the meter to be 5.87 per cent fast. The transmission pipe line was tested for leaks by shutting off all valves at the delivery end and maintaining a constant pressure on the line. The station meter then showed a loss of 20 to 25 g.p.m. No test was made of the valves which may have leaked part of this amount.

With a new 8-inch transmission line paralleling the existing 6-inch line, the existing line being repaired to reduce leaks, together with new pumps designed to operate under the conditions that would exist, it was estimated that the annual saving in power cost would be $2,333.00. On this basis, the change, made together with some additional improvements and additions in filter capacity, elevated storage and distribution system, was made. The power cost was reduced from $5,044.80 to $2,563.27 during an eleven-month period, a saving of $2,481.53 or $2,700.00 per year.

From these two illustrations it is apparent that high power costs for any given job do not depend solely on the cost of fuel or electric rates, but on the condition of the power consuming equipment in regard to efficiency and adaptability to meet the characteristics of the service for which it is used.

To maintain good pump efficiencies and low power costs, periodic checks should be made to determine whether there has been any change in the power consumption rate. This can be done by keeping an actual record of the gallons pumped for a given period and the kilowatt hours used during the same period, and by comparing the cost per unit with that when the pumps were first installed and operating at maximum efficiencies. In making this check, care should be taken that the pumping head remains the same as during the original period. The more accurate method of checking the pump operation is to make a complete test at the pumping station. Most utility companies maintain an industrial engineering staff well equipped to make these checks. This service is free of charge to the utility customers.

Thus it appears that electric power is meeting the requirements as a source of pumping plant power. With duplicate or triplicate sources available, there is greater assurance of a continuous and ample capacity of power to meet all emergencies. The dependability of the power supply is one of the factors taken into account by insurance rating organizations. Failure of power during large fires may cause thousands of dollars of damage, a sum which would pay the power cost for many years from a dependable power supply.

The flexibility of electric power permits maximum efficiency of operation with varying conditions of plant pumpage. In many systems the friction head is a sizable portion of the total head with maximum delivery. Frequently this can be materially reduced during long periods of pumping by the more extensive use of pumps of smaller capacity. A flexible power source permits such variation in requirements at minimum investment and operating costs. The many types of motors available for all kinds of drives and characteristics make the application of electric power simple.

Adaptability is a desirable feature of a power source especially for smaller pumping plants. In many sections the water supply comes from man-made reservoirs and lakes usually located in out of way places where land is relatively cheap. Often the only approach is by a road unsuitable for trucking. It is very desirable in such cases that the power source be adapted to the business and not the business to the power supply.

A clean source of power means a clean plant that builds pride of ownership and operation, and these factors act as a stimulant to the delivery of a better product and enhance employee safety and satisfaction. Cleanliness is a desirable quality for any operation whether it be in a water pumping plant or a factory.

The public is inclined to associate the condition of the product and the efficiency of the management with the condition of the plant producing the product. A dirty pumping plant often creates the idea of unclean impure water and neglectful management.

Electric power is the cleanest and most easily controlled source of power available. Water pumping plants can be made fully automatic in operation, kept clean and neat. In non-automatic stations the closing of a switch makes the starting of the largest motor as easy as that of the smallest motor.

These features make it possible to locate a pumping station in a fine residential section of a city or in a remote place in the country They permit economical and reliable management.

Maintaining Efficiency of Centrifugal Pumps

By George J. Poole

IN THE large pumping stations of today, there will be found a great variety of pumps and auxiliary equipment, all pertinent to the high efficiency of the modern pumping station. Since a discussion of each of these types of pumping equipment is a subject in itself, the author, in this paper, proposes to discuss only one type, electric-motor-driven centrifugal pumps, and to attempt to bring out some facts concerning them that will be helpful to water works men involved with the operation of large pumps.

The past two decades have seen the maximum efficiencies of large centrifugal pumps climb from 80 to 89 per cent, whereas the efficiencies of large motors have risen from 94 to 96 per cent, and each rise in efficiency has lowered pumping costs. It is understood that maximum efficiency of any centrifugal pump is obtained at rated output and critical head. How far a pump can be operated off this point depends upon the characteristic curve. A pump with a flat curve can be operated from three-quarters load to one and one-quarter load and still maintain its efficiency, whereas one with a sharp curve must be run at rated output and critical head.

Pumps with a flat curve are adaptable to direct pumping into a system having a reservoir remotely connected to the system, while pumps with sharp curves work better when pumping directly into a reservoir where the head is nearly constant.

In the Fridley Pumping Station in Minneapolis where the rate varies from 20 m.g.d. to 125 m.g.d. over a period of 24 hr., and the daily output ranges from 25 m.g.d. to 68 m.g.d. depending on the season of year and the amount of rainfall, the greatest difficulty is encountered in operating at maximum pumping efficiency.

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Equipment of Minneapolis Plant

Pumping equipment on the high lift pump floor at the Fridley Pumping Station includes: three 20-m.g.d. pumps operating against 240 ft. of head; two 30-m.g.d. pumps, operating against 250 ft. of head; and one 40-m.g.d. booster pump, operating against 65 ft. of head. The station is operated with 96 lb. pressure on the discharge header at night, 105 lb. in daytime, and 108 lb. during peak loads. Thus, the 240-foot head pumps can be run at night and the 250-foot head pumps in the daytime and maximum efficiency maintained. During peak loads, which often last for 4 or 5 hr., it is necessary to run four or five units. The 30-m.g.d. units, having a greater head, crowd the 20-m.g.d. units down to three-quarters load, and due to the flat characteristic curve of the 20-m.g.d. units, the loss of efficiency under this condition is about 1 per cent. If a pump with a sharp curve were used, the loss might be 3 or 4 per cent. This loss of 1 per cent efficiency means a rise in cost per million gallons pumped into the system of 12 to 26 cents, depending upon the head pumped against.

Pump Testing Technique

At the time of installation of each unit, an official test is made to determine its overall efficiency. These tests are made with very accurate instruments, and the resulting values are used as standards of efficiency which the unit should maintain throughout its life, while in good condition. A drop of 1 per cent in efficiency is allowed before a pump unit is overhauled.

When the official test is made, the wattmeter measuring the input to the motor is set to record the same value in kilowatt hours as the test wattmeters. This is done to correct for phase angle losses in the current and potential transformers, used with the wattmeters.

It must be understood that the wattmeters and transformers are stock instruments which are assembled and wired on the motor control board. When the current and potential transformers leave the factory, their phase angle correction factor is known. Rough handling due to shipping and erection, in nearly all cases, changes this value. Once they are erected the value remains constant, unless it is altered by a severe electrical surge.

If several sets of wattmeters and their respective transformers were attached to the same motor, no two of them would register the

same value unless their phase angle correction factor had previously been determined, and the factor applied to correct the reading. It is, therefore, much simpler to set the wattmeters with the test meters, which are portable and of a much higher grade than the stock instruments. These test instruments are very easily taken to a laboratory for checking.

Application of Tests

Application of this testing technique is as follows: When one of the units drops 1 per cent in efficiency, the flow meter, head gage, and suction gage are checked, and, if found correct, the test meters are applied to the motor. Should the fault be found there, the wattmeter is corrected; if not, the pump is examined for wear and broken impellers, etc. The pump is then repaired and efficiency returns to normal, saving the department 12 cents per mil.gal. on the water pumped.

An excellent example of the value of this method of testing is found in the experience with one of the units installed in 1918 in one of the Minneapolis stations. At the time of installation nothing was known of phase angle correction. The official test was made by the University of Minnesota Electrical Department, using three sets of electrical test instruments and averaging the results. The efficiency value obtained was 82.1 per cent. The test required ten days to complete. In 1931, another official test was made, taking into consideration the phase angle correction losses in the meter. At that time the unit was found to be 84.6 per cent efficient, and since power was being purchased on the efficiency basis, the knowledge that the unit was 2.5 per cent more efficient than rated would have resulted in a considerable saving over the 13-year period.

Applied to smaller units of, e.g., 750 g.p.m., the method has proved very satisfactory in enabling the engineer to keep a check on a unit at all times. Some of the Minneapolis records show that pumps of this size lose their efficiency much more quickly than the larger units, the reason for this being that the smaller units are generally of higher speeds, and the pump division rings are fitted more closely, allowing faster wear and erosion to take place. Checks made on pumps of the 750-g.p.m. class show efficiency drops of 4 per cent in one year's time, but replacement of the division rings usually brings it back to the original value. At $1\frac{1}{4}$ cents per kw.hr., however, 4 per cent loss in efficiency amounts to a considerable loss in a year's time.

Proper gland packing plays an important part in maintaining efficiencies of both large and small pumps. On the large Minneapolis units, which often run for 20 days without shutdown, leakage of air through worn packing, which occurs during the run, has cut the output rate as much as 1 m.g.d. without reducing the input to the motor. In some cases, leakage of air into a pump has caused loss of prime. Loss of prime on any pump operating on a suction lift is a constant danger to any pumping station operator, especially to a unit pumping raw water that contains sand or gravel, as considerable damage can result by running the pump dry. This is a particularly important consideration in the operation of remotely controlled pumping stations. Frequent care should be given glands in this type of station. Experience at Minneapolis has included several instances where considerable damage to small pumps resulted from loss of prime caused by faulty packing. Damage consisted of burned out sleeves, bearings, and on one occasion, a burned out motor.

Pumps for Small Water Works

By C. C. Walker

FROM the tonnage of scrap iron which is contributed by pumping stations, it is evident that the major problem involved in any discussion of the subject of pumps for small water works, i.e., plants rated at 1 m.g.d. or less, is that of resolving proper methods for the selection of adequate and efficient equipment. In his experience, the author has come into contact with innumerable cases where all sorts of difficulties in pumping operations have been directly attributable to the improper choice of equipment. One instance in particular will demonstrate the unnecessary problems which may arise from the lack of adequate knowledge in this respect.

A small town was supplied by a well field located approximately a mile from the power station. There were four small wells in the field, each equipped with an air lift pump which discharged into a small receiving well. From there an air displacement pump discharged, through a mile of steel pipe, into a receiving well at the main pumping station. Steam-driven duplex pumps then took the water up and discharged it into the distribution system without further treatment. Due to leakage in the water line between the power house and the well field, sufficient water could not be delivered to the receiving well at the pumping station. The old air displacement pump was then replaced by a motor-driven, horizontal, centrifugal pump, the capacity of which was greater than the total capacity of the four wells. This condition no longer exists, as the four wells have been replaced by two properly constructed wells of larger diameter, equipped with motor-driven turbine type deep well pumps of proper capacity, and the leaking steel pipe by a new cast-iron line; but the wastage and unnecessary inconvenience involved in this

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and similar cases indicate the necessity for application of proper methods in the selection and specification of equipment.

This emphasis on selection, however, is not intended to imply that the problem ends at this point. Pumping is inextricably involved with the other features of water supply, and most particularly with piping. An instance in which a pumping problem resolved itself into one of faulty piping is a good example of this relationship.

Low pressure service in a small town was provided by a motor-driven centrifugal unit which pumped raw water through the plant. The static suction lift was only 5 ft., but the suction line, the size of which was adequate, was approximately 2,000 ft. long. A small capacity motor-driven reciprocating pump was used to prime the low pressure centrifugal pump. It was the author's problem to find out why it was no longer possible to prime the low service pump; and to determine what the difficulty was, he recommended that a foot valve be placed on the end of the suction line and a connection made, so that the suction pipe could be filled with water under pressure. When this was done the location of the suction line, which was laid under a cover of from 3 to 5 ft. was distinctly marked by fountains rising from the ground surface at nearly every lead joint in the line. The reason for priming trouble was then evident.

This is only one of a number of such cases, with which the author has come in contact, in which other features of a water works system have been directly involved in its pump failures, but it will serve to indicate that the scope of the pumping problem cannot be confined within the walls of the pumping station.

In the discussion which follows it will be the author's main purpose to make certain recommendations concerning proper methods of selection of pumping equipment, and in doing this he will deal only with those other features of the water works system which have, or should have, a direct bearing upon making a choice. Other factors than those discussed are recognized to be pertinent, but they must remain without the scope of this paper.

General Considerations

The first factors in the selection of any pump are concerned with general specifications regarding motive power, lubrication, control, cost and standardization. These are factors which apply regardless of the purpose for which the pump is to be used, and so must be considered as primary requirements.

Motive Power

Electric power is now so common, so well distributed, and the service so dependable, that, in most cases, it can be used in small water works pumping stations. The community, large or small, where electric power is not available, is so rare that it is seldom necessary to consider the use of either steam or internal combustion engines as a source of motive power for pumping service. In large water works pumping stations, steam is most often the economical power to use. In the few borderline cases which the author has investigated, he has found that the pumping rate below which electrical power is cheaper, and above which steam power is cheaper, is considerably higher than 1 m.g.d. The advent of the modern diesel engine has provided another source of cheap power. For small plants, however, installation costs may be excessive. This is especially true if treatment which requires the use of a number of motors in the operation of the plant is necessary. In such a case, of course, a diesel-engine-driven electrical generator is required, and this further increases the cost of installation. It is fairly well established that when interest on the investment is taken into account, purchased electrical power will prove to be the cheaper method in the majority of small water works.

Lubrication

In the matter of lubrication, it is the author's opinion that the use of oil is preferable to the use of water for well pumps operating intermittently, especially on deep settings with a low static water level, and for sand-pumping gravel wells. This seems to be true despite the claim that certain bearings and pump shafts are not affected by sand.

For water-lubricated pumps is claimed a greater efficiency, resulting from the fact that column losses are not as great as when oil is used. In many installations, however, efficiency is not of great importance, as is evidenced by the experience in one small town which recently purchased two turbine type deep well pumps.

In this instance, bids were received from seven different manufacturers offering pumps of different types, on which the greatest difference in over-all (wire to water) efficiency at the pump discharge flange was 10 per cent. Taking into consideration the estimated yearly pumpage, with current cost at 3 cents per kw.hr., the total

saving between the highest and lowest efficiencies amounted to less than $12 per year, in the pumping costs.

On the other hand, in larger installations, pumping against higher heads at higher rates, such a difference in efficiency, or even a smaller variation, may affect power costs by hundreds or even thousands of dollars per year; and in this event the merits of water as against oil lubrication, inasmuch as they affect efficiency, should, of course, be given serious consideration. If, in the foregoing case, for example, the pumps had discharged the same amount of water into the distribution system instead of through the treatment plant, the saving in power costs for the 10 per cent difference in efficiency would have been about $560, or approximately the cost of the pump and motor.

Control

The control facilities available constitute another factor to be considered in pump selection. Many plants which pump untreated water into the distribution system are equipped with fully automatic control. Such installations keep elevated storage tanks practically full at all times and, by so doing, are able to reduce operating costs to a minimum. Complete automatic control, however, introduces a number of problems which must be solved satisfactorily before general application is entirely feasible. Most important of these requirements is that water hammer and surging, especially on high head pumps with long discharge lines, must be held within reasonable limits. In one instance, about ten years ago, at a manually-controlled plant where water hammer was unrestricted, a current failure which occurred when the plant was pumping 700 g.p.m. against a total head of 125 lb. per sq.in. through a discharge line approximately 2 mi. long, the water hammer caused by the sudden stopping of the pumps almost lifted the whole pumping station into the air. Needless to say, adequate provision against such emergencies must be made before fully automatic operation can be relied upon.

It is the author's opinion that for these reasons and because cost, except, possibly, in the very small plant, will be greater than with manual operation, treatment plants should not be made fully automatic. Semi-automatic control, i.e., manual control using automatic warning or safety devices, seems definitely preferable for the average small water works. Using such a partially automatic system the operator may take full advantage both of the labor saving and safety features of control devices and of his own experience and

good judgment. On the whole, it may be said that manually controlled motor-driven centrifugal pumps are satisfactory in most small water works and that only in exceptional cases are other forms of control necessary.

Cost

Cost is, of course, a necessary consideration in the purchase of pumps. Since manufacturers, through the adoption of mass production methods, have reduced costs so that prices of the better grade of pumps are truly competitive, this factor is becoming less and less important. If construction or efficiency is made the determining factor in selecting a pump, the price can usually be neglected as a decisive factor.

Standardization

As previously noted, mass production has been accomplished by each manufacturer designing and making dies for casting standard casings. By using different diameter impellers in each of the series of casings, each manufacturer can meet all head-capacity conditions. Efficiencies, however, are not uniform for all diameters of impellers. Since casings are not standard, but vary among manufacturers, for any given head-capacity condition, efficiency will also vary among manufacturers, sometimes to a large extent; and this variation must, as already pointed out, be taken into consideration when high heads are involved.

Specifications for pumps for use in large water works frequently require special construction in order to obtain both high efficiency and dependable construction features. Such specifications are desirable and proper for large pumps, but small water works should normally use standard units and not require special features. This means that pumps by several manufacturers should be investigated for construction features, and for efficiency when that enters into the selection. Experience indicates that most of the misfit installations are due to the decision of the authorities to purchase from a predetermined manufacturer, regardless of pumping conditions.

Well Pumps

In addition to these general considerations in pump selection, certain other factors pertaining specifically to particular types of equipment are to be evaluated.

First to be considered in this connection are pumps suitable for installing in wells to discharge well water at or above ground level. Reciprocating, turbine and centrifugal pumps are all used for this purpose, the first two being most popular.

Some years ago, reciprocating pumps were almost universally installed for well pumping, their distinctive advantages being uniform pumping rates over a wide range of head and fairly high efficiency. These pumps, however, were very low in capacity, except in extremely large wells, such as are not usually found in small water works; they required frequent repairs and replacements of sucker-rods, valves and other parts; and their discharge was not stable.

On the other hand, modern motor-driven turbine-type deep well pumps, when properly chosen and installed, are durable, quiet, vibrationless, highly efficient and discharge at a uniform rate. In the past, their great disadvantages were the necessity for making frequent repairs and replacements and their low efficiency. At present, however, these difficulties have largely been eliminated although most manufacturers still specifically recommend that the pumps be removed from the well occasionally for inspection and replacement of worn parts.

Regarding well pumps in general, it should be noted that structural features, as well as efficiency, are to be given serious consideration, and that a pump with a steep head-capacity curve will give a more uniform rate of discharge as the water table rises and falls.

In this connection, too, the author would like to recommend the installation of a water level gage in all wells. While such an installation has no direct relation to the selection of a pump, it is mentioned here because such an instrument will contribute much to satisfactory operation, and because it will be helpful in forecasting future difficulties. A simple gage of this type can be made by the use of a quarter-inch pipe, preferably copper, the bottom end of which is below the end of the suction pipe, and the other end, at the top of the well, provided with connections for an air pressure gage and a hand air pump. If the elevation of the bottom of the air line is known, the water elevation can easily and accurately be determined at any time.

High Pressure Pumps

The other type of pumping equipment in general use in small water works plants is the high pressure pump, used for forcing water from receiving wells, clear water basins, etc., into distribution systems

and elevated tanks. Reciprocating pumps of both the horizontal and vertical types and various types of centrifugal pumps are used for this purpose.

The advent of dependable electric power has almost entirely eliminated the horizontal reciprocating pump, as it is almost never driven by electric motors. The single acting vertical type, known as the triplex pump, however, is in common use. It is a rugged, highly efficient and dependable piece of equipment, but is also heavy, unusually noisy, and occupies a comparatively large floor space. Modern centrifugal pumps are rapidly displacing it both in replacements and in new construction.

The perfection of a dependable 3,600-r.p.m. electric motor has done much to advance the design of centrifugal pumps. Even those of small capacity now have an efficiency comparable with the reciprocating pumps of a few years ago. Improved bearings, increased speeds and better designed impellers have combined to decrease size, weight and cost of pump units, and, strange as it may seem, to increase their efficiency and durability.

Originally, centrifugal units for water works service were double suction pumps of the split case type. Engineers and operators considered this type the only one suitable for water works operations. Impellers were not hydraulically balanced and thrust bearings were a necessity, even with the double suctions, which, theoretically, divided the stream of water so that half was led directly to each side of the eye of the impeller. The life of the bearings and, to a lesser extent, the life of the sealing rings was indefinite, requiring frequent replacement. Split cases permit replacement and repair without removing piping, valves, etc. Today, however, impellers are hydraulically balanced, even in the so-called "end suction" pumps, and this improvement has eliminated the necessity for end-thrust bearings. Bearings have been improved so that failure and replacement is the exception rather than the rule. Wearing ring life has been prolonged so that rings, too, are but very infrequently replaced. In this way most of the features which originally favored the use of the double suction split case pump have been removed. One bugbear, however, remains—the alignment of the pump and motor, which are usually direct-connected by a flexible coupling.

End suction centrifugal pumps were originally cheap competition pumps, built for and bought by contractors for construction service and meant to be discarded after five or six months' use. Today many

pump manufacturers are making end suction centrifugal pumps that compare favorably in workmanship, materials, design and efficiency with double suction split case pumps. The author's experience prompts him to recommend them for small water works pumping stations, especially if piping and pump space is limited.

In the selection of motors for these pumps, it will be well to remember that total pumping heads at small water works pumping stations are usually not constant and that a changing head on a centrifugal pump varies the quantity discharged and the horsepower required. The motor selected should have sufficient horsepower not only at the specified head and capacity condition, but, so that it will not be overloaded, at any point on the head-capacity curve.

Nearly all manufacturers make good pumps, but no manufacturer makes a pump that fits any and all specified pumping conditions. The selection of a proper pump is a more important problem than is sometimes realized. Impartial advice from a competent engineer will pay dividends in increased efficiency and in operating satisfaction. Such advice can be given only if the availability and reliability of power, method of control, conditions of service, characteristic curves, construction features and, sometimes, the financial rating of the manufacturer, have been taken into account; but if such advice is obtained and used in the future, the junk piles of unsuitable and unusable pumps and accessories should soon cease growing.

New Type Reservoir at Syracuse, N. Y.

By E. P. Stewart

WHEN the Syracuse Water Works was built in 1892-95, it was conceded that some day when the city expanded and homes were built on the surrounding hilltops of the four corners of the city, water would have to be supplied at a higher pressure. In 1910, the need for greater pressure in many places, especially east of the University, became so great that a high service system was built. The second conduit, which had just been completed, was, and still is, used for supplying this new system which provided approximately 45 lb. per sq.in. greater pressure than the low service portion of the system. Woodland Standpipe, the first high service storage unit, was built in 1910, and at that time its $1\frac{1}{4}$ mil.gal. capacity was sufficient for a day's supply.

During the next 20 years, real estate developments on the higher lands grew rapidly. Annexation to the city of some of the many surrounding highlands also increased the demand on the high service system. Older sections of the city, where the low service pressure was inadequate, were transferred to high service; and these increases in high service consumption ran far ahead of what had been contemplated. By 1925, the need for additional storage made it necessary to add Thornden Standpipe (capacity, 2 mil.gal.) to the system. These two standpipes serve as pressure regulators in addition to providing storage.

The topography of the city is such that the high service areas are widely separated, in four corners of the city, the greater portion of the areas supplied being in the eastern half. The No. 2 conduit supplies the high service system via two feeders, and in the event of a failure of the conduit or of the feeders across the city, recourse is had to electrically driven centrifugal pumps which lift the water from low service mains to the high service mains and storage units. If

A paper presented on March 27, 1941, at the New York Section Meeting, Syracuse, N. Y., by E. P. Stewart, Division Engineer of Water, Syracuse, N. Y.

there is a failure in the No. 2 conduit, either or both pumps can supply any part of the high service. In the event of failure of the high service feeders across the city, however, the 4-mil.gal. pump located at the water shop can pump directly from low service to the eastern high service areas.

Demands in the high service areas continued to increase until, by 1935, engineers of the Water Division were recommending the provision of at least 8 mil.gal. more high service storage. Peak consumption at the time reached as high as 9 m.g.d., making it obvious that the storage was entirely inadequate, as the two standpipes would provide but a few hours supply in the event of a failure in the No. 2 conduit, without the use of the emergency high service pumps located at Woodland Reservoir and at the Water Shops. Preparation of plans for a new storage reservoir and necessary feeders to be located near the University section were, therefore, begun.

The first consideration was the selection of a site which would be practical and economically possible. The ideal location for such storage, both from an economical and operating point of view, is close to the center of consumption and near the source of supply. Long feeders not only are costly, but must be made larger than short ones if the storage unit is to react quickly to variations in feed and consumption, and thereby give the maximum circulation in the storage unit. The most desirable location for a reservoir of the proper elevation was on Morningside Hill, located about $\frac{2}{3}$ mi. from the end of the high service feeders from Woodland Standpipe and on the south edge of the highly developed University area. Another advantage of the location was that the city had just previously acquired a part of the hilltop for park purposes, so that it was necessary to acquire only three additional acres on the west side of the hill and an easement for a portion of the feeder line from the reservoir site to the end of the Woodland high service feeders, this line being 24-inch pipe except for 700 ft. of 36-inch pipe laid immediately northwest of the reservoir.

As soon as the Water Division construction forces had completed the installation of the second intake in Skaneateles Lake* in 1938, the equipment and men were transferred to the reservoir site, and work on the project, which began late in the fall, continued through 1939 and part of 1940.

* STEWART, E. P. Installation of a 54-Inch Steel Intake Line. Jour. A. W. W. A., **31**: 759 (1939).

Design of Reservoir

The reservoir consists of three circular units located immediately adjacent to each other along an axis through the center of the hill which extends in a northwest-southeast direction. The center unit of the three tanks is 171 ft. in diameter, and the smaller units flanking it on either side are 111 ft. in diameter. The total height of the structure is approximately 34 ft., of which 10 ft. is below ground and 24 ft. above. This gives a capacity of $10\frac{1}{2}$ mil.gal. when the reservoir is filled to a 33-foot depth.

The unusual design in three units located immediately adjacent to each other (Fig. 1) was followed for several reasons. The shape of the hill was such that the maximum capacity of storage could be obtained by a structure either oval in shape or made up of three separate circular units. Several designs were made and studied, but the one used was considered most practical, safe and economical because of the stresses involved in other structures. It was deemed necessary, too, to construct the reservoir wholly on original ground. Were it not for this decision, fills could have been made which would have allowed a structure of different shape. Finally, the construction used had a decided advantage over one single large unit in that it made it possible to clean or work on one unit at a time without putting the entire storage out of service.

As the city has had a great deal of satisfactory experience with the use of steel and gunite in reservoir construction, considerable study was given the design of a reservoir utilizing these two materials. All-gunite and all-steel constructions were considered. The final decision was to employ three steel cylinders of all-welded construction for the sidewalls and covering these walls inside and out with 2 in. of mesh-reinforced gunite, the inner coat of gunite extending across the bottom of the reservoir and thickened to a total depth of from 3 to 5 in.

By this design, the stresses produced by the weight of the water are carried by the steel plates, the gunite forming a protective coating, inside and out, to the steel and a water-tight bottom where all of the stresses due to the weight of the water are transmitted to the earth. The maintenance cost of the reservoir should be very small as it will not be necessary to paint the steel work. Moreover, the gunite finish on the outside provides not only a durable protection to the steel, but a pleasing appearance which it will be possible to enhance

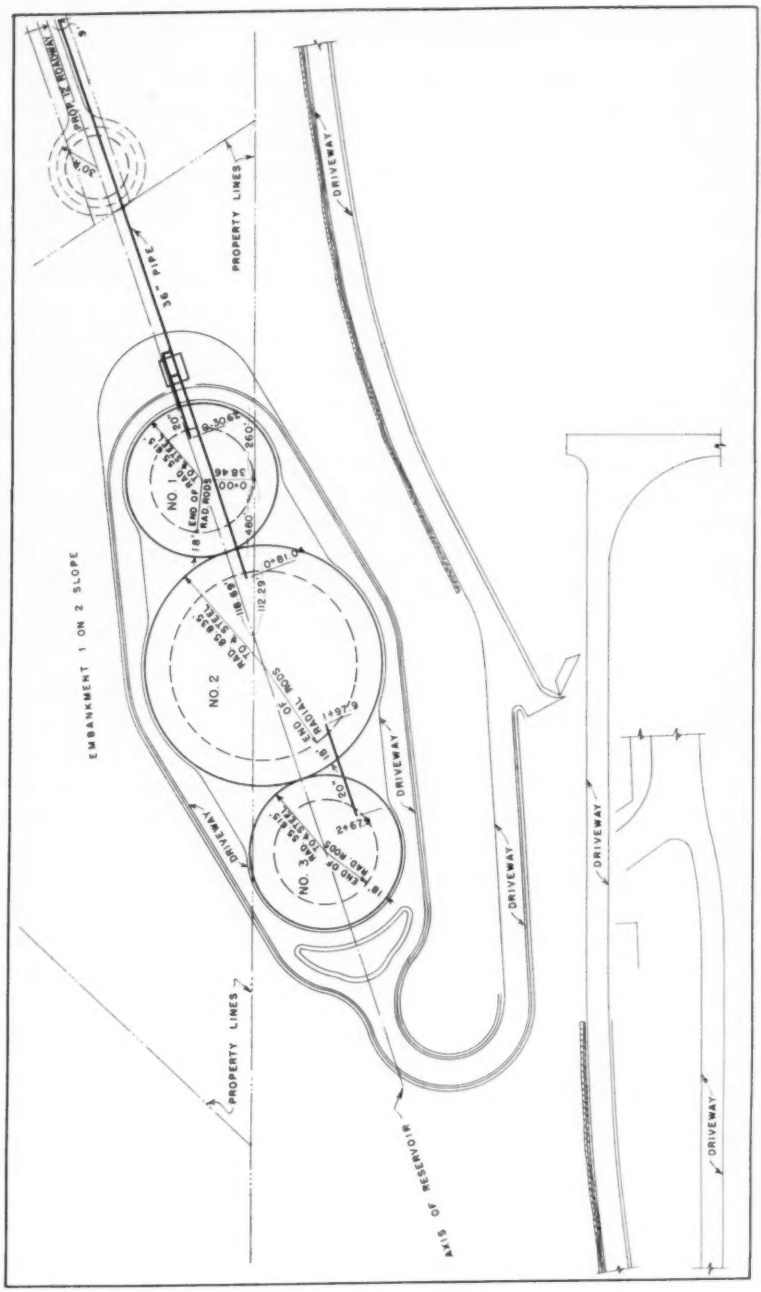

FIG. 1. Final Design of Morningside Reservoir and High Service Feeders

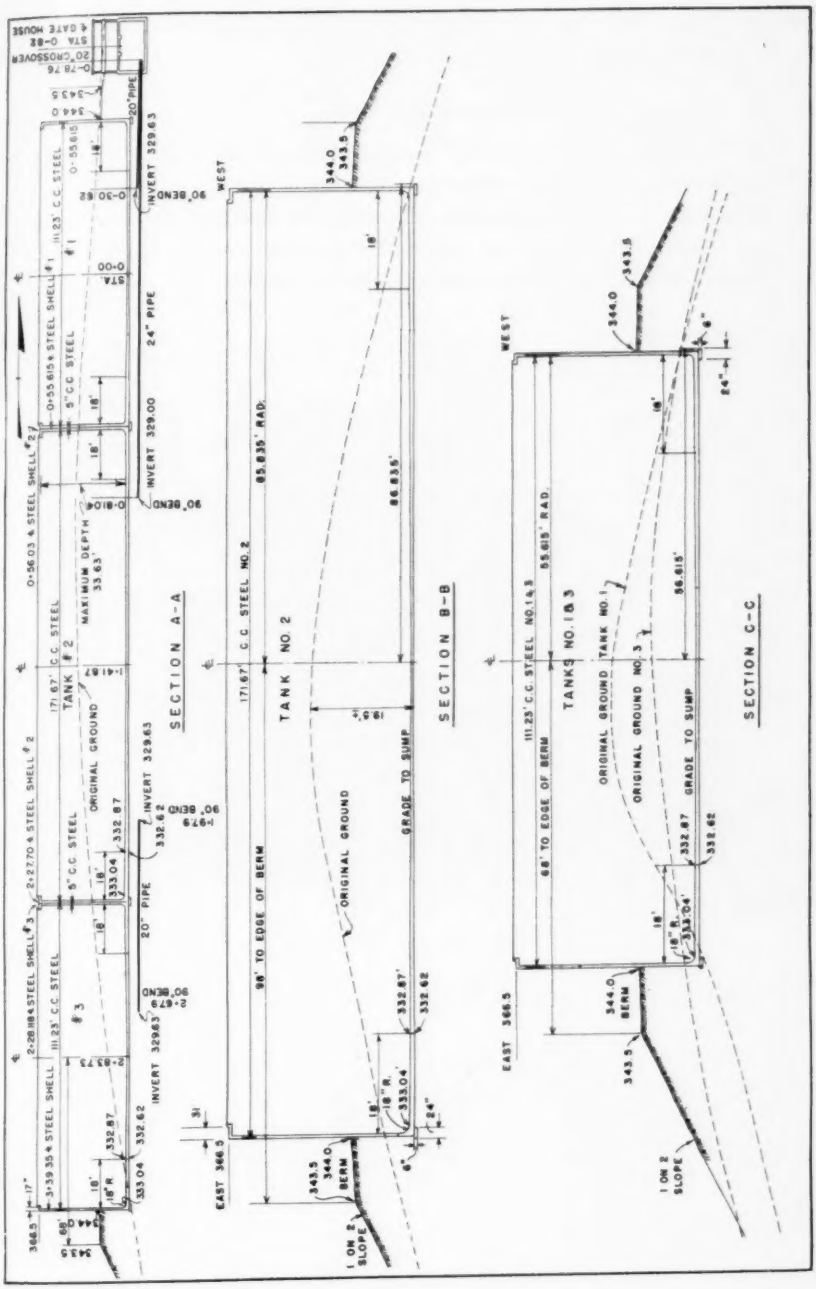

FIG. 2. Typical Center Line Sections of Morningside Reservoir

by the use of vines, a treatment which will harmonize well with the type of park in which the tanks are located.

Erection of Tanks

The first step in construction was to level off the top of the hill with power shovels and to complete the grading with scrapers and some hand labor. The material excavated was used to form a berm around the reservoir by dumping it on the existing slopes to form an artificial embankment with a slope of approximately 1 on 2 (Fig. 2).

FIG. 3. Steel Tanks Before Application of Gunite

This material was well compacted by the rolling action of the trucks used for conveying it.

As the material which was excavated was, in general, very hard clay, the design called for simple foundations; i.e., rings of reinforced concrete 2 ft. in width and 6 in. in depth, on which to support the steel cylinders. Where softer material was encountered, excavation was made to a depth sufficient to obtain good bearing, the maximum depth of foundations being about 3 ft.

The embankment itself was not built up to final grade before the erection of the steel cylinders. In order to provide ample working

space around the cylinders and to facilitate erection, material for the top 5 ft. was placed on the slopes of the embankment and cast into place after the structure was completed. The embankment was also omitted for a space of 5 ft. away from the cylinders to allow working space around the bottom 5 ft.

In the steel cylinders (Fig. 3), as is the practice in modern steel tank construction, all of the steel plates, which vary in thickness from $\frac{1}{4}$ to $1\frac{1}{8}$ in., were joined together by electric welding. In all there are over two miles of field welds. Not a single rivet was used in the entire structure. Tests made of sample pieces of welding on plates of thicknesses comparable to those used in the steel cylinders showed more strength in the weld than the plate itself. Over 100 cores were cut from the steel plates across the welds for tests and inspections, and these showed almost perfect fusion of the plates and the weld metal.

Because the tanks were but a few inches apart on the axis line, it was necessary to construct wind girders inside the cylinders. These wind girders are 17 in. wide on the two small tanks and 31 in. wide on the large. They soon became known as "cat-walks," as they provided a ready means of working around the top of the tanks.

Mesh Reinforcement

All of the gunite was heavily reinforced with electrically welded galvanized steel mesh. The mesh used, both on the outside and inside of the tanks, is 4 in. by 4 in., with wire sizes as follows: No. 6 on the exterior surfaces; No. 6 on the interior surfaces to an elevation 10 ft. down from the "catwalk"; No. 7 on the interior surfaces from this elevation to the bottom, and No. 4 on the bottoms. For the gunite encasing the "catwalk," 3 in. by 3 in. No. 10 wire mesh was used.

The contract for erecting and welding the steel cylinders included tack-welding $\frac{5}{16}$-inch and $\frac{1}{4}$-inch steel rods on 3-foot centers on the exterior and interior surfaces of the steel cylinders. The rods were crimped at the point of contact, thereby spacing the rod 1 in. from the steel plates. The steel reinforcing mesh was fastened to these vertical rods by means of large spikes which were sprung under the rods and over the mesh. The mesh, which is 8 ft. wide, was placed in vertical strips (Fig. 5).

To provide the reinforcement required where the bottoms and sides of the tanks meet, $\frac{1}{2}$-inch radial rods, in lengths of 6, 12, and 18

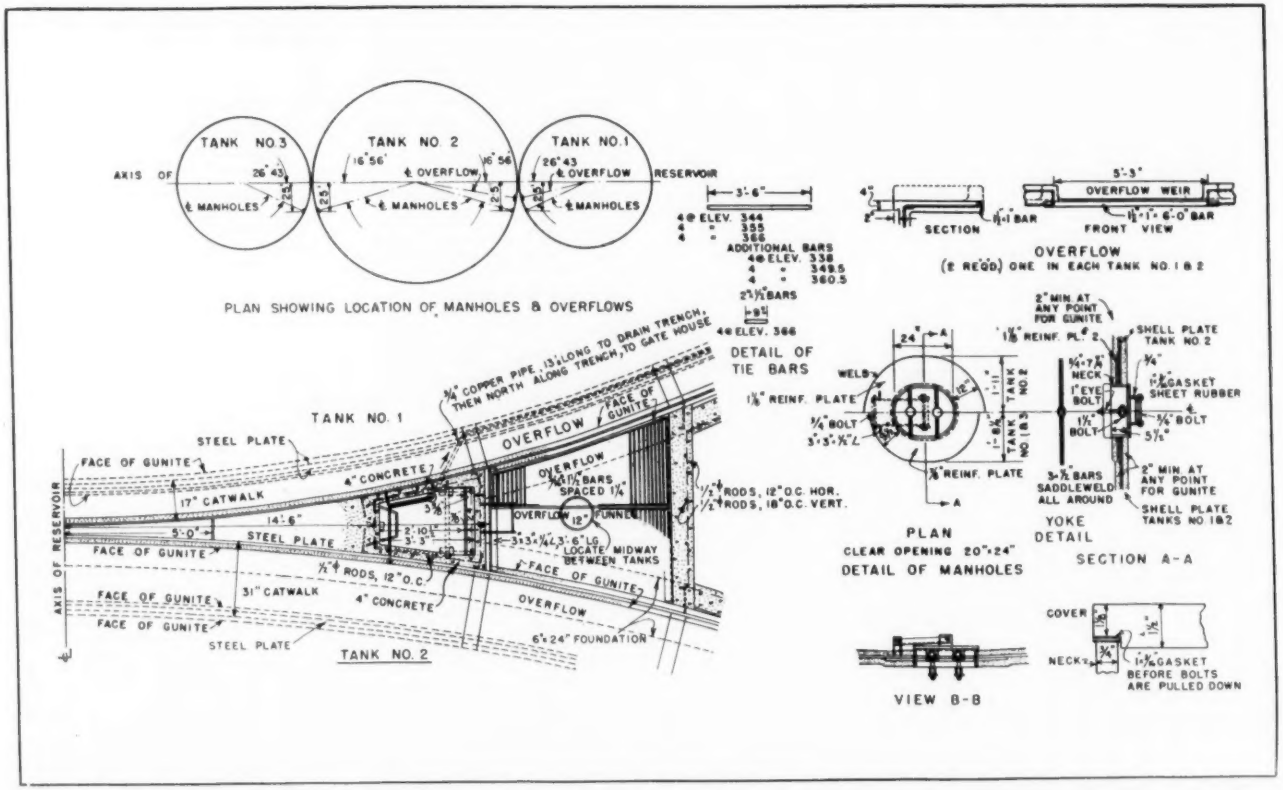

FIG. 4a. Typical Gunite and Concrete Details

FIG. 4a. Typical Gunite and Concrete Details

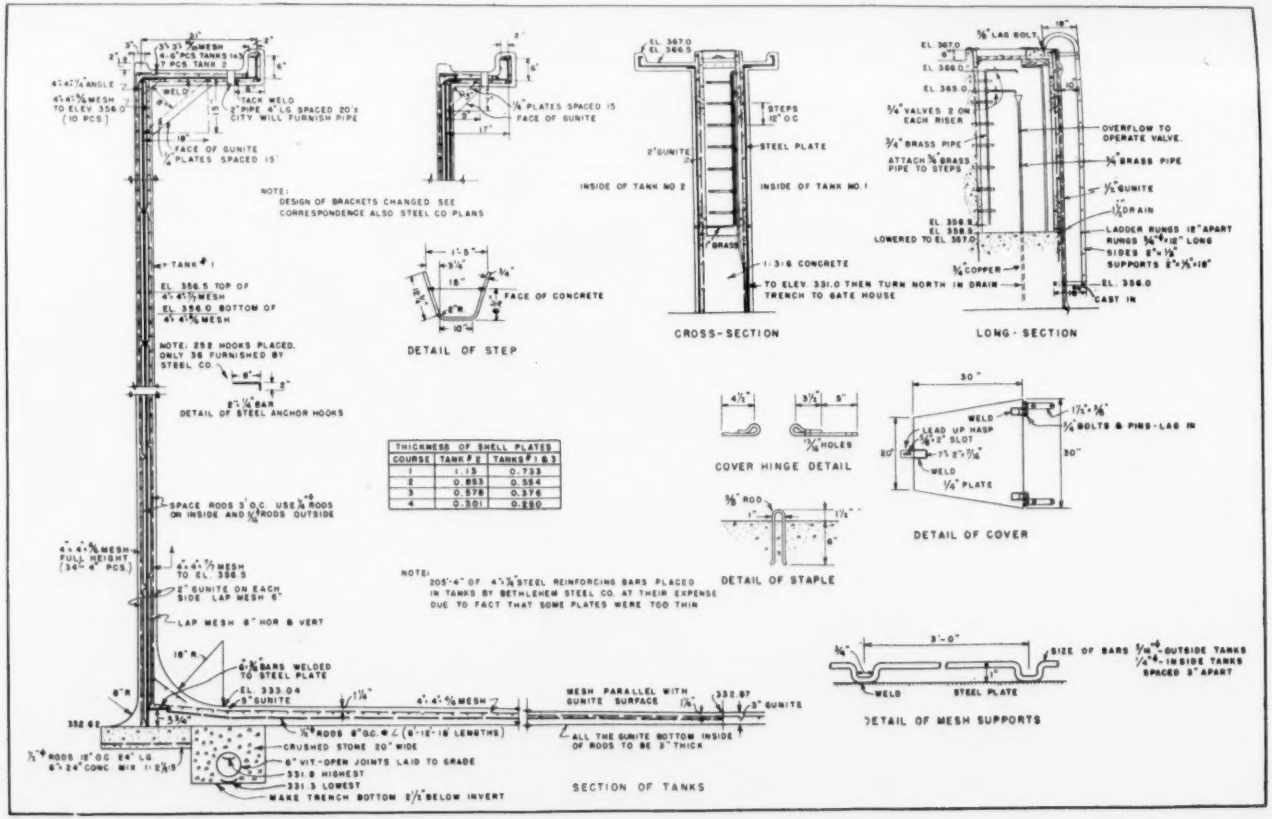
DETAIL OF STEP
CROSS-SECTION
LONG-SECTION
COVER HINGE DETAIL
DETAIL OF COVER
DETAIL OF STAPLE
DETAIL OF MESH SUPPORTS
SECTION OF TANKS
DETAIL OF STEEL ANCHOR HOOKS
NOTE: DESIGN OF BRACKETS CHANGED SEE CORRESPONDENCE ALSO STEEL CO PLANS
NOTE: 292 HOOKS PLACED, ONLY 36 FURNISHED BY STEEL CO
NOTE: 205'-4" OF 4"x3/8" STEEL REINFORCING BARS PLACED IN TANKS BY BETHLEHEM STEEL CO. AT THEIR EXPENSE DUE TO FACT THAT SOME PLATES WERE TOO THIN
THICKNESS OF SHELL PLATES
COURSE | TANK # 2 | TANKS # 1 & 3
1 | 1.15 | 0.733
2 | 0.853 | 0.584
3 | 0.578 | 0.376
4 | 0.301 | 0.250

FIG. 4b. Typical Gunite and Concrete Details

ft., spaced on 8-inch centers at the steel cylinders, were used in addition to the mesh. A steel ring, 1 in. by 6 in., which was drilled to receive the bent ends of the rods, had previously been welded at right angles to the steel cylinders, 6 in. above the foundations. The purpose of this reinforcement is to distribute the stress, caused by the expansion of the steel when it is under pressure, over an 18-foot angular ring of bottom gunite adjacent to the steel cylinders. The maximum thickness of gunite through the fillet, where sides and bottoms meet, is about 12 in., reducing to 5 in. at a point 20 in. from the steel cylinders and tapering to 3 in. at the inner ends of the 18-foot rods.

FIG. 5

FIG. 6

FIG. 5. Placement of Steel Reinforcing Mesh on Exterior of Steel Tank
FIG. 6. Application of Gunite on Exterior of Steel Tank; showing swinging staging supported by outriggers

Application of Gunite

"Guniting" is a trade name for a process of placing a mixture of sand and cement at high velocity. Placement is effected by means of compressed air, a special "gun," hose and nozzles. Material applied by the process develops a strength approximately twice that of ordinary concrete and the greater density and water-tightness at construction joints developed through its use makes it desirable for reservoir construction.

The equipment for the work was rented, but all of the application of the gunite was done by skilled city workmen; and the finish coat, which was applied in 1940, was done entirely with city-owned equipment.

Practically no scaffolding was used in the gunite work. All of the interior sidewalls were shot from rafts and most of the exterior work from swinging staging supported from outriggers which were attached to the same rafts (Fig. 6). The finish coat was applied from a portable staging which contained an elevator operated with winches. It was mounted and moved on a trailer which was pulled by a tractor. By means of this equipment, gunite was applied continuously from the top of the tank to the ground.

The mix used was 1 part cement to $3\frac{1}{2}$ parts sand on the bottoms, and a 1 to 4 on the sidewalls. A batcher plant and concrete mixer, located at the south end of the grounds, were used to proportion and mix the cement and sand. The mix was then transported to the cement guns in dump trucks from which it was elevated to bins over the guns by a belt conveyor.

Four of the largest size cement guns were used (Fig. 7). The nozzles were $1\frac{1}{4}$ in. in diameter at the tip. Nozzle velocity was measured with velocity meters and controlled to values giving the best grade of gunite as determined in research work carried on by the city in previous gunite jobs.

All of the gunite on the interior of the tanks was cured by flooding. Gunite on the bottoms was kept wet with a hose, and when a bottom was completed it was completely inundated. Circumferential strips of gunite about 5 ft. high were shot on the inside walls each day and completely covered with water during the night. Succeeding strips were shot from rafts and the water again admitted to the tank to cover the gunite shot and to lift the raft to the next shooting position.

Curing of the Gunite

A rather novel method was used in curing the finished coat of gunite on the exterior surfaces. Before applying this coat, the gunite previously shot was sand blasted lightly and kept wet for a period of 24 hr., before the flash or finish coat was applied. After the application of the finished coat, the new gunite was kept wet continuously for four days. The method used in both instances was to lay sections of $\frac{3}{4}$-inch pipe, perforated with $\frac{1}{16}$-inch holes spaced 12 in.

apart, around the top edge of the tanks, in such a manner that, when subjected to a small head of water pressure, jets of water were directed on the gunite. The water immediately spread out over the surface so that the entire surface of the tank was covered with a thin film of water. This method worked very well, and was found to be much superior to previous methods which involved hanging burlap on vertical gunited surfaces and attempting to keep it wet.

A great deal of study was given to expansion and contraction problems in connection with the shooting of the gunite. As the steel

FIG. 7. Application of Gunite to Bottom of Steel Tank; showing spray gun nozzle; note insulation band near bottom of tank in background

cylinders were not tied into the concrete foundations, they were free to give and take with temperature variations. It can readily be seen that such movement would be undesirable when the gunite was shot to form the fillet where sides meet bottoms. To reduce this movement to a minimum, a band of gunite, approximately 5 ft. in height, was first shot around the outside of the cylinders, beginning at an elevation about 9 in. above the foundation. A similar band was then shot on the inside (Fig. 7). This insulation, plus the effect of the curing water on the gunite, practically eliminated movement in

the cylinders. The outside fillet, joining the exterior coating with the foundation, was then shot and the trench surrounding the tanks backfilled. When the bottom was finally shot against the steel sides to meet the gunite previously applied, the backfill around the tanks was kept saturated to effect further uniformity of temperature. No observable movement had taken place before the gunite had taken its initial set.

Concrete Fill Between Tanks

As the distance between the steel cylinders on the axis was but 5 in., it was not possible to gunite the exterior of the cylinders for a distance of $14\frac{1}{2}$ ft. on either side of the axis of the tanks. The design, therefore, called for filling this space with concrete.

Some problems arising from this plan were immediately apparent. If the concreting were done with the tanks empty, its weight would distort the sidewalls; and this distortion would be much greater when the tanks were filled with water, as the tanks could not expand along the axis lines except on one side of each of the small tanks. On the other hand, if the concreting were done after the tanks were filled, the steel would contract and tend to pull away from the concrete when they were emptied. It was finally decided to fill the tanks with water each day to such a height that the thrust from the water pressure would balance the weight of the day's pour of concrete.

To insure a good bond between steel and concrete at all times, the steel was sand blasted prior to the pouring of concrete. Steel hooks had been welded on the plates in this area to distribute the pull of the steel in the concrete, thereby reducing the tendency to break the bond. Substantially the same method was used in the case of the gunite coatings, as the steel was completely sand blasted inside and out before the gunite was applied and the steel bars, tack-welded to the plates, acted as anchors.

Automatic Control Features

The gatehouse located immediately north of the reservoir contains valves for controlling the flow to and from the various units. One of the valves is a 30-inch automatic valve which shuts automatically when the water in the reservoir reaches a predetermined level. This action occurs daily as the maximum level of Thornden Standpipe is slightly higher than that of Morningside. An electric control system designed by engineers of the Water Division opens the valve

to allow flow to the high service areas when the pressure on the city side of the valve becomes .01 lb. less than that on the reservoir side. A mechanical feature regularly supplied with the valve opens it regardless of the electric control when the pressure falls about ½ lb. per sq.in.

To insure positive closing of the altitude valve, for a definite elevation of the reservoir, the north and middle tanks were tapped within the concreted space between tanks, about 7 ft. below the overflow, and these taps are connected to a riser pipe which spills through a goose-neck and an open break to another pipe which extends downward and under the north tank to the altitude valve. The elevation of the goose-neck is such that water spills through it into the pipe leading to the altitude valve at the desired shut-off elevation. This water actuates the pilot valve which closes the 30-inch valve. The elevation of the water in the reservoir will overrun about 3 in. during the period of closing of the altitude valve.

A small chamber in the concrete was provided to house these connections, and the transmitter of an elevation gage. The latter is also actuated by the same taps. As the chamber is insulated and heated by thermostatically controlled electric heaters, and as all piping and taps are below ice and frost lines, there is little danger of failure of operation in winter weather.

The elevation gage is electrically operated over a leased telephone line from Morningside Reservoir to the Water Shop. Thus, the elevation in the reservoir is known at all times by the men on duty at the Water Shop, and the information is relayed to Woodland Reservoir by telephone.

As a further factor of safety against freezing in the elevation control chamber, a thermostat was installed in series with the telemeter circuit, which breaks the circuit when the temperature in the pit falls below any set value. Operators at the Water Shop order an investigation whenever the circuit is opened, as indicated on the elevation recorder.

Normal operation of this reservoir is as follows: The reservoir is full in the early morning hours. As the consumption in the high service areas, especially in the eastern half of the city, increases, part of this consumption is furnished from Woodland Standpipe through the two high service feeders and part is drawn from Thornden Standpipe. When Thornden Standpipe drops a few feet, the automatic valve opens at Morningside and water flows from the reservoir

to the points of consumption. At the present time, during normal operation and daytime consumption, the reservoir may drop from 0 to 3 ft. In the evening, as the consumption decreases, the flow across the city from the west exceeds the demand, and both Thornden and Morningside storage units begin to fill. Both fill during the night hours, but Thornden continues to fill to a somewhat higher elevation after Morningside has shut off. The flow through the two high service feeders from Woodland Reservoir can also be regulated by the operators at Woodland, thereby controlling the levels of both the storage units.

While every precaution has been taken to guard against the overflowing of the tanks, it was still deemed necessary to provide overflow facilities in case of failure of these precautionary measures. The vertical stiffeners in the wind girders of the large tank and in one of the small tanks were cut away to provide for a maximum overflow of 4 m.g.d. A drain of sufficient capacity for this flow was laid from the overflow chamber to a storm sewer in a nearby street.

Landscaping of Grounds

As the view of the city from the reservoir site is exceptionally good, it was decided to construct a driveway through Morningside Park from the end of the main street to the top of the embankment. The width of the berm was sufficient for a one-way drive around the entire structure. Parking space was purposely limited, however, to discourage the use of this water supply property as a park.

As the reservoir is located in and adjacent to a park which has been left more or less in its natural state, it was felt that shrubs on the slopes would be more in keeping with the nature of the park than would grass. This method of landscaping the grounds, it is believed, will result in much less maintenance cost and, at the same time, will harmonize with the surrounding setting. Over 10,000 shrubs of different varieties and small evergreen trees were used in this work.

W.P.A. labor was used in the construction of the driveway and in the shrubbing of the slopes. The Paving Division of the Engineering Department had charge of the construction of the pavement, and the Parks Department co-operated with, and advised, the Water Division regarding the landscaping. All of the evergreen trees used were donated by the New York State College of Forestry at Syracuse University.

Construction of Earth Reservoir Embankments With Road Oil Linings

By Duncan A. Blackburn

THE earth embankment concrete-lined reservoir is probably the most common type of water storage in use today. Such reservoirs can be built economically, are easy to maintain, and are comparatively safe, if properly constructed.

The first earth embankment reservoirs were constructed by the so-called cut and fill method; that is, the earth was excavated from the center of the reservoir and deposited on the sides to form the embankment. This material was built up in layers and consolidated by rolling. In most cases, the rolled earth in the bank would be denser than the original ground upon which the embankment was placed, and because the deposited material had better compaction than the original ground under the fill, uneven settlement and the breaking up of the concrete lining after the reservoir was put in service resulted.

Where the bottom material was not consolidated, a horizontal crack inevitably appeared in the concrete lining between the fill and the original ground. Many other cracks also appeared, both horizontally and vertically, indicating the uneven settlement in different parts of the embankment. These cracks in the lining would allow water to pass through and, if not repaired, would undermine the embankment. The author knows of two instances where such leakage caused the failure of a portion of a reservoir bank.

To overcome this uneven settlement of reservoir banks, a new method of construction was developed and first used in the construction of large oil storage units in the Southern California oil fields. In this technique, the sides of the reservoirs were over-excavated a

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A paper presented on October 25, 1941, at the California Section Meeting, Los Angeles, by Duncan A. Blackburn, Assistant Engineer, Pasadena Water Department, Pasadena, Calif.

distance of six or eight feet in back of the finished subgrade, from the ground line down to the bottom of the reservoir. When the bottom elevation was reached, selected material was deposited in layers and rolled evenly until the sides were built up to the ground line. From this point the inside section was carried up with the remainder of the embankment.

The ideal soil for bank construction has been found to be a mixture of sand and clay, which breaks up easily but which will bind together when properly moistened and tamped. When such material is properly placed and compacted into a homogeneous mass, very little settlement is likely to occur.

Good material is not always available for reservoir construction. The site for a new reservoir is generally selected because of elevation and nearness to the point of service, available material for building the embankments being a secondary consideration. Where the material cannot be compacted with water, an embankment can be constructed and made absolutely leak-proof by means of road oil.

The Pasadena Water Department has in two instances used road oil in the construction of the fill on the interior of reservoir embankments. In the first case, the site for the reservoir was at the mouth of a small canyon. The material available was a fine silt, deficient in clay or other binder, which would melt away in contact with water. The reservoir site was directly above a fine residential district which would be damaged if a break occurred in the reservoir walls. It was decided that the extra cost of road oil for the construction of the reservoir was warranted in order to insure the continued use of the reservoir and to guard against possible property damage. Two years ago a second reservoir, using the same type of construction, was built. In this reservoir, too, the ground available was deficient in bonding material, the top soil for a depth of three or four feet being a light loam, below which were strata of sand and gravel in which large cobbles were embedded.

Cut and Fill Procedure

In constructing an oil-lined reservoir of this type (Figs. 1 and 2), the site is first cleared of all brush, roots, stones, and other materials which are not suitable as fill material. The area, upon which the water-bound fill is to be placed, is plowed to a depth of 6 in., watered sufficiently to moisten the earth, and rolled and tamped with a petrolithic tamper, weighing not less than 800 lb. per lin.ft., until the

earth is thoroughly compacted. The excavation is then started and the fill is placed on all ground which is lower than the top of the cut. The initial cut (Fig. 3) is made around the entire reservoir between a line approximately 8 ft. into the reservoir banks from the finished surface of the lining and a line approximately 3 ft. inside the reservoir. This excavation is carried to a depth of from 24 to 30 in. below the

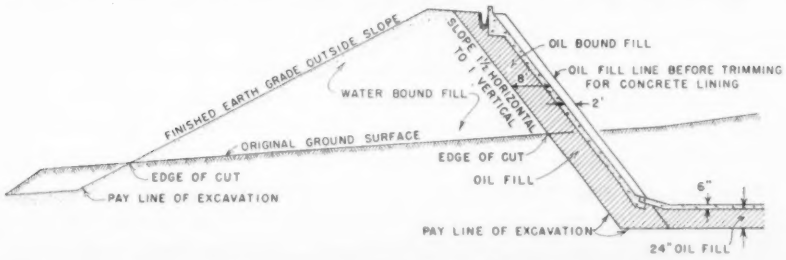

FIG. 1. Typical Section of Oil-Fill Reservoir Bank

FIG. 2. General View of Oil-Fill Type Reservoir Construction; showing material in center to be removed to construction fill

floor elevation, the depth being fixed by the amount of trim material available from the sides, as hereinafter described, which is to be placed on the bottom. If more material is obtained from the initial excavation than can be used in the water-bound fill, since the water-bound and oil-bound fills must be brought up together from the top of the cut, it may be necessary to stockpile this extra material. This

has not, however, been found necessary on any of the projects undertaken by the Pasadena Water Department.

After the initial excavation has been carried to the proper depth below the floor, the area is plowed to a depth of 6 in. and an application of road oil made, thoroughly mixed, then rolled until firm with a petrolithic tamper. The oil-bound fill is then started upon this prepared subgrade.

In constructing the embankments, the earth is removed from the interior of the reservoir to the bottom of the initial excavation. The material obtained is spread in uniform horizontal layers of not more than 4 in. in depth on the embankments. All stones larger than 4 in. in any dimension are rejected as fill material. In the case of water-

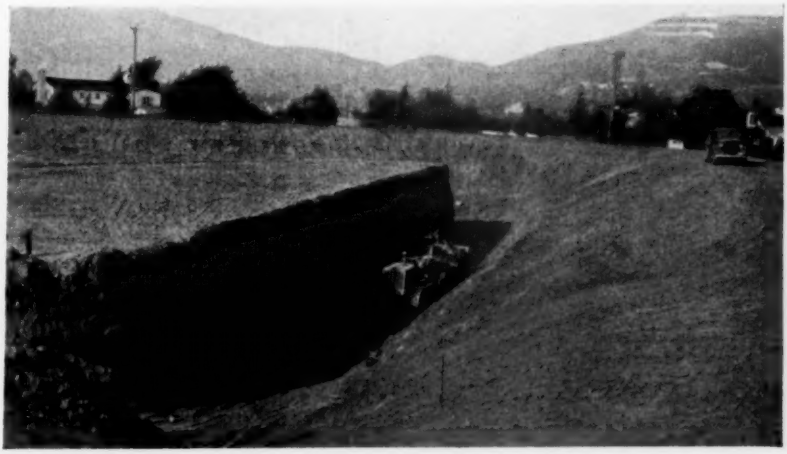

FIG. 3. Excavation of Initial Cut Preparatory to Starting Oil Fill

bound fill, sufficient water is added to each lift of earth to make it pack well. Each layer is then thoroughly rolled with a petrolithic tamper, weighing not less than 800 lb. per lin.ft. of roller, until the sheep's feet are working on hard ground not over 3 in. below the surface, before additional earth is deposited.

The oil-bound fill is carried up from the bottom of the initial excavation and is usually constructed 10 ft. in width, sufficient to provide for the use of mechanical mixing equipment on the grade. The inside of this fill projects approximately 2 ft. horizontally into the reservoir from the finished surface of the lining. This is done to permit trimming off the improperly compacted material along the edge of the fill.

After a 4-inch lift of earth has been spread over the grade, it is loosened with a harrow. A coat of road oil is then applied uniformly over the surface and cut in by following the oil spreading equipment with a spring tooth harrow to prevent the oil from collecting in low spots in the grade. After the first oil application is mixed into the soil, enough additional oil to impregnate the earth should be added. The oil is spread either by hand-spray or spreader truck, and it usually requires two to three applications with occasional spotting where the earth seems to lack the proper amount. The oil is mixed into the soil by the use of spring tooth and disc harrows. The initial mixing causes the earth and oil to form balls about the size of hens' eggs, which are broken down into a homogeneous layer of oiled

FIG. 4. Oil Fill Under Construction; showing lift where mixing is almost completed

earth by further mixing (Fig. 4). After completion of the mixing, the oiled fill is rolled with the petrolithic tamper as previously described for water-bound fill.

Incidental Factors Involved

Some difficulty may be experienced in preventing overfill inside the reservoir, particularly if the disc harrow is about 10 ft. wide. This may be prevented to a great extent by the use of a drag behind the harrow. The best results from the use of the spring tooth harrow are obtained when the teeth are kept sharp so that they will dig through the lift being mixed into the layer below.

Air temperature has considerable influence on time required to mix the oil and earth thoroughly. Cool mornings require a great deal more mixing time than is required in the middle of the day.

Oil demand varies with the type of soil, fine soils requiring considerably more oil than sandy soils. The overall oil demand will vary with each project. Experience in Pasadena has shown that one barrel of road oil will compact approximately 1.4 cu.yd. of oil fill in place.

The type of oil used in this construction is known as SC-2, in accordance with the standards set up by The Asphalt Institute.

Co-ordination of personnel is very vital when placing oil fill. If much time is lost during the day, one lift of completed fill may have to be sacrificed. The contractors on the Pasadena projects attempted to make three lifts per day.

Completion of Construction

After the completion of the entire fill and the berm has been brought to grade, the inner slopes of the embankments are trimmed to true subgrade. The material trimmed off the banks is then deposited on the over-excavated floor area of the reservoir in uniform layers not over 4 in. in thickness and is thoroughly compacted with a petrolithic roller. No additional oil is added to this trim material. After completion of fill in the bottom of the reservoir, it is graded and rolled with a roller having a weight of 250 lb. per lin.in. of tire.

If the reservoir design requires that the completed subgrade of the floor be cut into for outlet sumps or piping, oil fill must be placed at least 24 in. below and 16 in. on each side of such pipes and structures. This material is all compacted by hand tamping.

The rough trimming of the inside slopes is usually done with a rotary scraper or carry-all. After the loose surface has been removed, it is necessary to root up the surface of the compacted fill in order to get the balance of the material down into the bottom of the reservoir. Contractors shoud be warned to use care not to cut below subgrade when they do the rough trimming, as it is expensive to replace material in low spots on the sloping banks. The trouble usually occurs when the caterpillar tractor, pulling grading equipment, first goes over the top of the bank. There is a danger of cutting the top edge of the fill too low and cutting too deep about 6 ft. below the top of the bank.

After the rough trim is completed, the banks are fine-trimmed to bring them to true subgrade. This part of the trimming is most

difficult since the compacted fill is extremely hard. The author has seen two methods used: setting headers for the use of a roadway subgrader or setting grading headers and doing all fine grading between them by hand. In his opinion, the latter gives the best results and does not seem any more expensive.

The last project of this nature by the Pasadena Water Department had numerous low spots in the finish grade inside of the reservoir. After considerable experimenting, it was found that the oil fill could not be rebuilt by using a pneumatic tamper as it left a fracture line between the original fill and the new material. The method found to be most practical was to broadcast well mixed oil earth across the low spots and compact it with a petrolithic tamper pulled up and down the slopes. This method seemed to knead the new material into the bank perfectly. After this refill, it was necessary to trim the slopes again.

After completion of the interior trimming of the reservoir bank, preparation is made for placing a 6-inch reinforced concrete slab over the entire bottom and sides of the reservoir.

The Pasadena Water Department's experience with the oil refill type of reservoir bank construction, together with the present method of constructing the concrete lining, has proved, to date, to be very satisfactory. The oil refill increased the cost of the reservoir construction approximately 15 to 20 per cent, but this was more than offset by a marked decrease in maintenance costs and a reduction of leakage. The total leakage and evaporation losses of the most recent construction are about 15 per cent of the reservoir capacity per year, which is considerably less than the 300 per cent figure which obtained with some of the older types of construction.

It is the author's belief that this type of reservoir construction should be considered for new projects in a fast growing urban area where there are few sites for new reservoirs available at suitable elevation and in close proximity to the area to be served.

The Use of Softened Colorado River Water for Home Gardens

By Oscar C. Magistad

WITH the completion of the Metropolitan Water District's aqueduct and distribution system, Colorado River water will be available in Southern California. On the basis of exhaustive tests, methods and cost of softening this water for industrial and home use have been determined. A description of the process was given in June, 1939, by Julian Hinds, Assistant Chief Engineer of the Metropolitan Water District of Southern California (1). He states that for agricultural purposes it is better to use the water without softening, and to this the author believes all soils men and agriculturists will agree. Additional information about the softening plant is given by Montgomery and Aultman (2). The present paper will discuss the use of treated Colorado River water on the lawns, gardens, and shrubbery of home owners in the Metropolitan Water District.

The water reaching Cajalco Reservoir will closely approximate the composition of Colorado River water at Yuma. Table 1, giving the composition of Colorado River water, is based on 43 weekly samplings and analyses during the calendar year 1939, omitting 4 samplings in January because of a flood in the Bill Williams River and 4 samples in September and October because of heavy local rains. The analyses were made by the Division of Irrigation Agriculture, Bureau of Plant Industry, and supplied by C. S. Scofield. The United States Geological Survey has furnished the author with analyses and discharges at Willow Beach since 1934, from which a weighted five-year average, from September 30, 1934, to September 30, 1939, yields 690 p.p.m. dissolved solids. Adding 5 per cent for evaporation loss between

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Willow Beach and the softening plant, this value becomes 724 p.p.m., nearly equal to that given in Table 1.

Values for 1940 at Willow Beach and Yuma are said to exceed slightly the 1939 values of Table 1. Hinds (1) and Montgomery and

TABLE 1

Estimated Composition of Colorado River Water at Cajalco Reservoir

COMPONENT	QUANTITY	
	*e.p.m.**	*p.p.m.*
Cations:		
Calcium	5.15	103
Magnesium	2.32	28
Sodium	4.62	106
Total	12.09	
Anions:		
Carbonate	.14	8
Bicarbonate	2.45	149
Sulfate	7.09	341
Chloride	2.43	86
Total	12.12	
Sodium	38%	
Boron		.14
Total dissolved solids		746
Total hardness as $CaCo_3$		374
Total carbonate hardness		123
Total non-carbonate hardness		251
Conductance $K \times 10^5$ @ 25°C		115

* "An equivalent per million (e.p.m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million (p.p.m.) by the chemical combining weight of the substance or ion.

"This unit has also been called 'milliequivalents per liter' and 'milligram equivalents per kilogram.' The latter term is precise, but the former will be in error if the specific gravity of the solution is not exactly 1.0." A.S.T.M. Standards—1940; Part III, p. 541.

Aultman (2) give the estimated concentration of Cajalco Reservoir water as 609 p.p.m. total dissolved solids. Their analyses were based mainly on records obtained at Grand Canyon prior to 1930. Causes for the increased salinity figures of recent years may be the trans-mountain diversion of fresh water, subnormal rainfall, or inade-

quate data for the original estimate. At any rate it would seem that the water reaching the softening plant would have about 750 p.p.m. total dissolved solids, 38 per cent sodium and 350 to 400 p.p.m. total hardness computed as calcium carbonate.

The boron concentration in Colorado River water is 0.14 p.p.m. as compared with 0.62 p.p.m. in the Los Angeles aqueduct water. On this score, the Colorado River water is almost ideal, having enough boron for good growth of most plants, yet not too much for even the most sensitive.

Effect of Prolonged Irrigation With Saline Water

A portion of the irrigation water applied to land evaporates from the surface; a large part seeps into the soil from which it is removed by transpiration from plants; and some drains downward below the root depth. Runoff under good irrigation practice is usually not large. About 500 lb. of water is transpired for each pound of dry matter produced. In the past it was considered good agriculture practice to reduce runoff, surface evaporation and root zone drainage to a minimum and to utilize all the water, or as much of it as possible, for plant growth. It is now realized that in irrigated regions some root zone drainage is necessary.

Irrigation water such as that from the Colorado contains about 1 ton of salt for each acre-foot of water. In the Imperial Valley about 5 acre-ft. of water per acre is required each year for alfalfa. It is readily understandable then that, with 5 tons of salt per acre added annually, there must be some provision for removing this salt or so much would accumulate in the surface soil that agriculture would be impossible. For this purpose, drainage is necessary—a fraction of the irrigation water should drain downward beyond the root depth to carry away the accumulated salt.

Irrigation Water and the Soil Solution

The soil solution, which is thought of loosely as the water bathing the soil particles, even though it may be only a thin film of water in cases of soils near the wilting point, varies greatly in composition, depending upon the nature of the original water, the composition of the soil colloid, and presence or absence of previously accumulated salts in the soil. Kelley (3) has shown that on a sandy loam, near Riverside, with good drainage the concentration of salts in the soil solution (calculated at a moisture content corresponding to the

field capacity) was about three times as great as the concentration of the original irrigation water. On less permeable soils, drainage is impaired and salts tend to accumulate so that the concentration of the soil solution may become very great. Heavy rains or heavy irrigation will tend to push these concentrated soil solutions downward below the root zone. Gilman (4) shows that on Ramona Loam after several years of low rainfall and light applications of irrigation water (1.77 ft. per acre), the concentration of chloride was found to be:

0– 3 ft.	horizon	from	1.2	to	2.4	M.E.	or	42.6	to	85.2 p.p.m.
3– 6 "	"	"	2	"	25	"	"	71.0	"	887.5 "
6–10 "	"	"	4	"	81	"	"	142.0	"	2,875.5 "

The soil solution in this well drained soil, he states, contained from 2 to 150 times as much chloride as the original irrigation water. After a winter of heavy rainfall, new samplings indicated that the concentration of the soil solution had been very much reduced. Thus, it may be seen that on well drained soils, copiously irrigated, the concentration of the soil solution may be as low as two or three times that of the irrigation supply, while on heavy soils, with small additions of irrigation water and low rainfall, the concentration of the soil solution may be 50 or 100 times as great as that of the irrigation water.

Since the soil colloids are bathed in the downward moving irrigation water, it is understandable that chemical reactions will occur between these colloids and the salts present in the water. One of the principal types of reaction is that of base exchange in which cations exchange between the colloid and the water until both are in equilibrium. This process is chemically similar to that used in water softening by zeolites. If the water is hard, and contains a large amount of calcium and magnesium, and the soil has a relatively large store of absorbed sodium, some sodium will go into solution. Usually the process goes the other way around, the soil being relatively high in calcium and magnesium compared with the solution, and sodium enters the soil colloid. Kelley, *et al.* (5) state: "The ratio of Na to Ca in the solution has relatively great influence on the absorption of Na. If this ratio is not greater than 2 to 1, very little Na will be absorbed, but as this ratio exceeds 2 to 1 the absorption of Na tends to increase proportionately." There are, however, other reactions, such as precipitation as calcium carbonate, sometimes as the sulfate, or by plant absorption, which tend to remove calcium from solution.

All these reactions tend to increase the Na : Ca + Mg ratio and when the soil solution is concentrated by evaporation or transpiration, the ratio may increase markedly. Under these conditions, when the soil solution is concentrated, it is most likely that there will be sodium entering the soil colloid.

Sodium saturated soils are very greasy to the feel. The colloid swells and the soil pores close up. Aeration is diminished. If the soil colloid becomes relatively saturated with sodium, the pH value of the soil solution may become dangerously high and all these factors are injurious to plant growth. The process is a steadily cumulative

TABLE 2

The Principal Soil Types and Areas in the Los Angeles and Pasadena District

SOIL TYPE	WEST LOS ANGELES	EAST LOS ANGELES	PASADENA
	acres	*acres*	*acres*
Hanford fine sandy loam	13,082	1,299	1,363
Ramona loam	10,598	3,885	7,411
Chino silt loam	4,602	320	—
Altamont loam	3,616	211	256
Chino clay loam	2,989	51	—
Altamont clay loam	2,778	3,674	79
Ramona clay loam	2,778	1,696	—
Ramona sandy loam	—	—	7,501
Miscellaneous	8,381	4,621	8,260
Total	49,824	15,757	24,870

one because, with swelling of the soil, colloid drainage is impaired and the soil solution becomes more concentrated.

For consideration of the nature of the soils in the Los Angeles and Pasadena areas, there have been obtained, from soil maps, the principal soil types in three areas: (1) the City of Los Angeles west of the river, south of Los Feliz Boulevard and following city limits, except at La Cienega Boulevard, and excluding the harbor and harbor strip; (2) Los Angeles east of the river; and (3) Pasadena from Foothill Boulevard, on the north, to the Southern Pacific Railroad on the south and San Gabriel on the east. The principal soil types found in these areas are given in Table 2.

Hanford fine sandy loam is the major soil type in West Los Angeles. It is of recent alluvial origin and is usually underlaid by stratified

deposits of sand, silt or gravel. This loam is, therefore, fertile, porous, easily drained, and well suited to irrigation agriculture.

At the other extreme are the Altamont soils which are residual, derived from shales. The Altamont clay loam, for example, is dark gray to black in color and usually has a heavier subsoil. On such a soil, of which there are over 5,000 acres in Los Angeles, drainage is poor. The Altamont loam is more permeable.

The Ramona soils are older than the Hanford and are derived from old unconsolidated water-laid deposits. The subsoil is usually heavier than the surface soil and may have compact layers which impede drainage.

Chino soils, like the Hanford, are of recent alluvial origin derived from granite and schistose igneous rocks. This soil may contain some lime. The subsoils are usually heavier than the surface soil and drainage is often restricted.

Effect of Irrigation on Los Angeles Soils

For lawn and garden purposes, people are prone to water the soil too lightly. Many people do not have sprinkler installations and it is too tedious to hold the hose or move it about. Delivery rates are apt to be low because of few or small nozzles. As a result it is estimated that the average householder in the region applies less than 2 ft. of water annually, whereas twice this amount would be more nearly adequate.

The average annual rainfall of the Los Angeles district is about 15 in. This precipitation sometimes comes in heavy downpours and because of surface runoff, is not effective for leaching purposes.

The probable result of a continual irrigation of Los Angeles soils with softened Colorado River water is an interesting speculation. Eaton (6) states that waters having a sodium percentage of 65 are of doubtful quality while waters with less than 50 per cent are satisfactory. Kelley (5) would put the limit a little lower, in the general region of 1 equivalent of sodium to 1 of calcium plus magnesium, that is, a sodium percentage of 50. With the relatively high total salt concentration of Colorado River water, and with a sodium percentage below 50 or 60, it would seem that this water could probably be used continuously on the well drained Hanford soils, but there would be a decided probability of disastrous results on the heavy soils such as the Altamont clay loam. This statement is based on the assumption that softened Colorado River water is used continuously, which eventuality is very improbable.

Effect of Saline Water on Plants

Although investigators have studied the tolerance of agricultural plants to alkali since the time of Hilgard, on the whole but few precise data have been accumulated. In general, experiments have been conducted in such manner that the actual concentrations at the plant roots have been unknown or extremely variable or such that there has been little assurance that the plant was supplied with the accessory elements now known to be essential.

A summary of results was published in 1936 by Kearney and Scofield (7). They indicate that sugar beets, strawberry clover, Bermuda grass and Rhodes grass are most likely to succeed on strongly saline soil, containing 0.8 to 1.0 per cent salts. Among ornamental and shade trees, they list cottonwood, black locust, honey locust, Chinese elm, Russian mulberry and some eucalyptus varieties as suitable on moderately saline soils, and recommend pomegranate and tamarisk as shrubs.

Eaton (8) pointed out that plants growing in salt solutions often appeared normal and that only by comparing them with others grown under similar non-saline conditions could one establish the amount of growth reduction which had occurred. Thus, a farmer or householder may believe his plants on saline soil to be healthy, yet they may, nevertheless, be stunted. More recently, at the U. S. Regional Salinity Laboratory, it has been demonstrated that salty conditions may change the internal anatomy of plants before external symptoms are visible.

Considerable acreages of irrigated lands have been abandoned, and a large fraction of land in the west, now irrigated, is in danger of having yields reduced to unprofitable levels because of saline conditions. To gather more information on the action of irrigation waters on soils, and on the joint action of water and soil on the plant, a regional laboratory was established at Riverside, Calif., in December, 1937. This Federal laboratory is part of the Bureau of Plant Industry. Building the laboratory and obtaining a staff took most of the time in 1938 and 1939, but results on some phases are now becoming available. The laboratory is co-operating with the western states, and their appointed representatives confer with the laboratory staff on the problems and research program.

While the work program to date has dealt mainly with plant and soil studies in the greenhouse and laboratory, the employment of an irrigation engineer will permit the staff to undertake field experiments in the near future.

Thus far in the plant studies at the laboratory, it has been learned that the quality of the irrigation water is of extreme importance. Crop plants have been grown in various synthetic salt solutions and their growth and behavior measured. During the 1939 season, experiments were conducted with cowpeas, squash, cotton, milo, sugar beets, tomatoes, and alfalfa in sand cultures of varying salt concentrations. At Riverside the average dry weights of the entire plant minus roots were as follows: (In the case of sugar beets, roots were included and tops discarded.)

	Treatment	*Average Relative Yield*
1	Basal nutrient solution	100
2	Base solution + 50 e.p.m. Cl, 10 Ca, 15 Mg, 25 Na	86
3	Base solution + 100 e.p.m. Cl, 10 Ca, 30 Mg, 50 Na	56
4	Base solution + 100 e.p.m. SO_4, 20 Ca, 30 Mg, 50 Na	70
5	Base solution + 200 e.p.m. SO_4, 20 Ca, 80 Mg, 100 Na	32
7	Base solution + 100 e.p.m. Cl, 90 Ca, 5 Mg, 5 Na	65
8	Base solution + 100 e.p.m. Cl, 5 Ca, 90 Mg, 5 Na	52
9	Base solution + 50 e.p.m. Cl, 2.5 Ca, 2.5 Mg, 45 Na	70
13	Base solution + 200 e.p.m. SO_4, 10 Ca, 180 Mg, 10 Na	38
14	Base solution + 200 e.p.m. SO_4, 10 Ca, 10 Mg, 180 Na	31

It must be borne in mind that the concentration in sand beds shown above should be compared with soil solution concentration and not that of irrigation waters. We see from the data above that on an equivalent basis, sulfates are less toxic to plants than chlorides. Eaton (9) on the basis of earlier work stated that "a tendency is shown for sulfate to be about half as toxic as chloride to some plants, but the lemon is apparently four or more times as tolerant to sulfate as chloride."

As regards cations, comparing Treatments 7 and 8, plants are more tolerant to calcium than magnesium. Again, comparing Treatments 3 and 7, it may be noted that Treatment 3 with 50 per cent sodium does not give as good yields in a perfectly drained sand culture as does Treatment 7 with 5 per cent sodium. The reduction is not so great and emphasizes the belief that sodium is harmful not so much *per se* as by its effect on the soil, resulting in turn in poorer drainage, more concentrated soil solutions, and a higher sodium percentage. Confirmation of this is available in a study of two 13-year old grapefruit groves, as reported by Eaton (9). Both were irrigated with Colorado River water (12 e.p.m.). In the first, on Superstition sand, the displaced soil solution of the third foot (considered representative) contained 20.6 e.p.m. and gave a yield, in 1936, of 546

lb. of fruit per tree. In the second, on Holtville silty clay loam, a yield of less than 100 lb. per tree was obtained in the same year. The displaced soil solution of the third foot contained 178.4 e.p.m. of which 56 per cent was sodium. On the sand, little salt accumulated and the grove produced well, while on the silty clay soil, salt accumulated in the subsoil and the grove suffered very seriously.

It is known that there are tremendous differences among plant species as regards their tolerance to salinity. Thus, at Riverside, in 1939, the following yields were determined in a sand culture tank containing 100 e.p.m. of chloride salt plus basal nutritent solution as compared with the yield in a control bed the base nutrient solution of which is taken as 100.

Cotton	83.9	Tomatoes	51.4
Sugar beets	82.0	Milo maize	34.8
Alfalfa	60.0	Squash	20.0
Cowpeas	51.8		

From these figures it may be seen that 100 e.p.m. of chloride reduced the yield of sugar beets 18 per cent in a sand culture as compared with an 80 per cent reduction of yield with squash in the same sand bed and under identical conditions.

Use of Colorado River Water

The discussion to this point has been on the thesis that treated Colorado River water would be used to the exclusion of any other irrigation water throughout the year. The need for additional water in the Los Angeles area at the present time is not great, and for the next few years most of the cities in the District will probably require only a relatively small quantity of additional water from the Colorado River Aqueduct. The water from the Los Angeles Aqueduct, with a total dissolved solid content of 311 p.p.m., total hardness of 109, and 48 per cent sodium (10) is undoubtedly superior to the softened Colorado River water and should be used as long as it is available. To mix treated Colorado River water and Los Angeles Aqueduct water would be desirable, but perhaps impracticable, at least for Pasadena. It may be assumed, then, that not so many years hence certain districts of Pasadena and other cities will use Colorado River water almost exclusively. A suggestion is made at this time that insofar as is practicable, the use of Colorado River water be confined to the areas of permeable soils, such as the Hanford fine sandy loam. It would also be desirable to have more information on the possibility

of blending the Los Angeles Aqueduct water and the Colorado River water, both from the standpoint of boron content and salt content.

Studies should be made concerning household "hardeners" as well as "softeners." Home or estate owners who could afford to do so would certainly be interested in hardening the water to be used in the garden. Possibly the District could install and service these units very cheaply with the calcium and magnesium compounds they obtain in the softening cycle at the softening plant.

The softening plant will produce large quantities of lime. Probably the District could convert this to calcium sulfate and apply it on the gardens of those who request and pay for the service. The soil itself will work as a zeolite, but the materials must not be so drastic in reaction, or in concentration, that plant growth is inhibited. For this reason, calcium sulfate, calcium silicates, and, in general, calcium salts of weak bases or relatively insoluble salts are used as soil applications to combat an increasing sodium percentage in the base exchange complex of the soil.

A whole new approach to water softening has been made possible by the use of anion exchangers (10). The process seems to be too expensive in its present state, but although it is new and costly, a few years research may well make the process economically feasible. There has also recently become available a new carbonaceous zeolite (10) which has the ability of removing sodium as well as calcium and magnesium from waters. This cation type of exchanger operates on a hydrogen cycle and its use on high sodium waters may be feasible.

Summary

In closing, the author should like to plead for facts and more facts. Just as the Metropolitan District made such a fine study of methods of softening water, a thorough study of the effect of this water on the particular soil types to be encountered is now needed, together with information about the effects of the water on a host of plant species ranging from shade trees to small flowers. It is true the U. S. Regional Salinity Laboratory at Riverside is doing work in this field, but it has a limited budget and will have to restrict its work to agricultural crops. Additional work by the state or by the Metropolitan Water District would be highly desirable.

Probably further study would indicate that "we can have our cake and eat it too"—that soft water for the bath and kitchen, with a hard-

ness below 100 p.p.m., and water with a sodium percentage below 50 or 60, which will not have an appreciably deleterious effect on soil and vegetation in the garden, will both be available. In the light of present knowledge, this does not seem entirely probable in the case of Colorado River water, so some compromise will undoubtedly have to be made.

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Mutual Water Companies and Domestic Water

By L. E. Blakeley

THE first Mormon pioneers came over the Wasatch Range more than 90 years ago, settling in Utah's dry desert valleys. Before 12 years had passed the settlers had formed 90 co-operatives to share the costs and work of bringing mountain water to the desert. Those were the first mutual water companies. Today, principally in the states west of the Great Plains, over 2,500 mutual water companies, operating on a non-profit basis, bring water from streams, rivers, lakes, and wells to the dry soil. Over 175,000 water users hold mutual membership, averaging 80 members to a company."*

Development of these mutual irrigation companies into domestic companies during the past 50 years is an interesting study. The high concentration of population near Los Angeles has not brought true urbanization to the vast acreage served by mutual water companies. It is safe to say that the bulk of service falls in what is termed by some sociologists the "rurban," i.e., neither rural nor urban, area. There appears to be a distinct culture developing in Southern California, which, outside of the industrialized area, is closely tied to the major agricultural sections. In each settlement there are a few retired folk, largely farmers from either local or eastern areas, the necessary stores and implement houses, transportation and storage facilities, dwellings for those directly and indirectly connected with the local agricultural crop, and, generally along the highways, adequate facilities to supply the needs of tourists. It has been compared by some to the community culture of Connecticut, with Spanish instead of New England architecture, without some of the problems of the mill town, but with equally difficult problems of a migrant population.

A paper presented on October 24, 1941, at the California Section Meeting, Los Angeles, by L. E. Blakeley, Chief Engineer, Santa Ana Valley Irrigation Co., Orange, Calif.

* Quotation from Circular A16, Farm Credit Admin., Washington, D. C.

Transition from the early California Spanish rancho, with its cattle and grain and its isolated homes and poor transportation, to the present "rurban" development, with its 1- to 50-acre holdings and concentration of packing and processing plants, has been met by the mutual water companies in various ways. If generalization is permissible in a field so broad, it may be said that the original companies, with riparian rights on living streams, are still predominantly agricultural in their usage. Late-comers into the field, whose supplies come from the "holes in the ground," which have been taken as a matter of course by those who have grown up in the section, but which are so astounding to many eastern visitors, have been able to make the shift to domestic service more readily. In other localities, private, municipal, county, and state water utilities have been organized and extended to meet the needs of urbanization.

The original mutual companies were formed by rugged individuals who understood the value of a truly co-operative venture. Agriculture, with its many variables, which are a part of universal forces which we can discuss but not control, is at least a venture and a way of life. Development of the sources of water supply, however, is an adventure in orderly and economic control of a natural resource, and its legal aspect as well as its physical conditions are in a constant state of flux. Records of the courts of California are replete with battles over water rights and claims. When the shotgun proved ineffective in preventing diversion of early surface streams, the matter was taken to court. The groups of settlers who joined in these truly co-operative corporations have maintained their rights over the years at considerable expense and by constant vigilance. In recent years many of these water suits have been dubbed "friendly," but while members have learned to co-operate in many ways, there are forces and interests at stake which are vital, and which can frequently be settled only by court action.

The California Mutual Water Companies Association comprises 48 members, serving 150,000 acres. The greater part of this area is purely agricultural, but many of the companies have both domestic and irrigation service; and by them, standards set by the State Board of Health must be met.

Mutual water companies frequently come into the picture when a small tract of land is subdivided. Due to low lift from the underground basin in the Coastal Plain, thousands of individual pumping plants serving from one to forty acres were installed when the land was farmed. As land was split up for residential purposes, equities

in the plants and distribution system were sold with the land. Other subdividers would put on a whole tract and furnish cheap or free water for a period as an advertising feature. Now that the wells and equipment installed in the Twenties are about worn out, there are an ever-increasing number of complaints and neighborhood quarrels about payment of the bills. Most of such troubles are in the poorer residential and marginal farming areas.

The State Real Estate Law which has been in effect for several years requires assurance of water supply before residence property can be marketed; but there are many inadequately served tracts which offer a challenge to the non-tax-supported companies to find an economically sound solution. Court action to partition the rights of various owners is indicated in some cases. In others, where a majority of the owners are residents, a mutual company or organization usually can be effected. Where there is a shifting population some type of state or county agency may be the best answer, as taxes can then be levied to meet all expenses.

State Control of Mutual Companies

Due to complaints over payment of bills and other matters, which have been made to the State Railroad Commission and to the State Division of Water Resources by aggrieved members of these many somewhat irregular mutual companies, it is extremely likely that efforts will be made to bring certain operations of all mutual water companies under some form of State control. It is likely that a complete system of cost accounting for mutual and governmental water producers and distributors as thorough as that required of private public utilities in the State of California would be of value in determining the proper type of system to be installed in each troublesome area, and would help to secure sound financing programs for all such organizations.

The problem of correcting abuses without inflicting undue restraint on normal operation of sound mutual companies is one which merits very serious consideration in the near future. It has been found very difficult to obtain farm loans on properties where the water supply is impaired, and the net result is a spotting of low valuation properties in an otherwise normal area.

Quality of Irrigation Water

Sanitation is not yet a great problem with the bulk of mutual water companies which depend upon underground supplies. Knowledge of

polluted underground sources, however, is causing some concern for the future. There is an area in Los Angeles County where the upper strata have been polluted with industrial and cesspool wastes so that an individual can no longer economically finance a well on his own property for domestic purposes. In other limited areas, ground water is of doubtful quality for irrigation and domestic use due to natural causes. Such conditions will tend to limit development of individual or mutual companies and force the area to depend upon supplies imported by governmental agencies. The major problem of sanitation lies with the old established "ditch" companies which rely to a large extent on surface streams. These companies are located in nearly every county in Southern California.

Sterilization of gravity irrigation water has not been effected by any major mutual water company. When the companies were first formed, as far back as Utah and California history goes, the mountains were a wilderness, and the Water Purification Section had no reason for existence. When some early settler developed a case of typhoid after drinking irrigation water from an open ditch, it was considered good training for the rest of his family and his neighbors.

Today, with thousands of vacationing and weekending urbanites, the pollution and contamination of major surface streams is a matter to cause real apprehension. The dumping of urban wastes into streams, with or without adequate treatment, is an even greater problem than recreational use of the watershed. Use and re-use of irrigation water also contributes to the problem of the ultimate downstream user. The University of California has conducted some studies of this problem on the Santa Ana River Watershed.

Rights to flow of water have been quite thoroughly argued so far as the Southern California streams are concerned, but too little attention has been given to maintenance of the original purity of the water provided to the rancher. As long as he had enough to wet the soil no questions were asked. This scene is shifting, and studies are now being carried on by several governmental agencies to determine the required quality of irrigation water. This burden of technical research is one beyond the economic ability of agriculture to handle. The major problem is not one of its making (nor, perhaps, of its liking); and it is quite fitting that the cost of determining and maintaining quality of water be placed directly on those who despoil it.

To this end, it is believed that disposal of wastes should be under control of men trained in and responsible for water sanitation and supply so that the heritage of the past, in unpolluted and uncon-

taminated streams and underground basins, may be maintained. An undue burden is placed on agriculture to meet the changed conditions of returned water supply caused by municipal and industrial usage. Underground reservoirs once polluted are a continuing liability, both as to known extent and as to possible future encroachment on otherwise potable underground waters.

The mutual water company can distribute water only to its share owners and, thus, is in a position to limit its service to the class of use which it desires. Most of the irrigation companies have so notified all stockholders and it is believed that there is no liability for unauthorized use. Insurance rates for such liability are quite reasonable, which fact is a fair indication of the financial extent of the problem. The author knows of no recent cases on this matter, but developments of the future may throw a greater burden on the irrigation companies.

Tax Burden of Mutual Companies

While mutual water companies are set up under the general corporation laws of the state, there is no regulation of their rates by any state agency. Such companies which serve domestic water must, however, comply with rules and regulations of the State Board of Health, and with county health department orders where there are such bodies. Their accounting systems are not prescribed and, since they operate on a non-profit basis, many of them have not kept adequate accounts. Others, due to local circumstances, have maintained most complete records and are in a position to know the cost of every service. Most mutual companies are exempt from the Federal income tax under one or another clause of the tax act. Employees, the greater part of whose monthly time is spent on irrigation-water work, are not subject to the Federal Social Security Tax. Office employees, and others who are engaged in work on domestic water supply, are, however, subject to this payroll deduction. Additional contributions in the nature of deferred wages are required of the corporation. Benefit payments under the Act have commenced, and increased contributions appear inevitable. In fairness to the employees and stockholders, the actuarial soundness of the Act should be made a matter of economic, not political, study in the immediate future. Basically, this also is true in regard to the state unemployment tax, although some apparently conflicting rulings have been made in the past. The intent of the law seems clear, but, for many

reasons, once payment has been started, it is quite difficult to secure relief.

Local taxing methods and practice vary from county to county, and several large mutual companies having property in two or more counties are assessed by the State Board of Equalization. Gas and electric power rate regulation, which vitally affects cost of production, is vested in the State Railroad Commission; and one mutual company is served by two private public utilities and one municipally owned utility, thus being effectively cut off from the lowest power blocks.

It is quite true that "government," quite apart from "administration," is forced to broaden the tax base, and that direct and indirect taxes will account for an ever increasing per cent of the charges for delivery of water by mutual companies. The taxation problem is one which offers greatest concern as the trend toward increase is developing so rapidly. In this manner, at least, the costs of mutual water companies are subject to governmental regulation.

Shifting of tax burdens through formation of many publicly owned utilities represents another trend toward higher costs for taxpaying corporations. This subject, like that of co-operative buying for stockholders, is highly controversial but cannot help but be a matter for serious consideration in view of the intense economic struggle which is now going on. If private (including truly mutual) industry ceases to function, its contribution to costs of maintenance of the state must be absorbed by someone else.

Adequacy of Supplies

The search for adequate supplies is now almost entirely a matter of economics, chemistry, and politics, in the purest sense. There is only a small amount of economically salvageable water in Southern California, and at the present depressed price of many farm products, even the word "small" may be too large. With irrigation water being distributed on a cost basis as low as $5 per acre-foot as compared to municipal revenue of about $60 per acre-foot, there is no urgent desire on the part of harassed farmers to invest more money in their water systems, regardless of the needs of the future. There is an extreme disinclination to mortgage what future they may have to bring water to undeveloped lands, unless that land carries its full share of the new water rights and development costs.

Under present water district enabling acts it is quite difficult to secure a method of voting whereby the man whose equity in his

property is directly mortgaged has a way to control the issuance of bonds or other tax items. Tenant or migrant voting on direct financial obligations is a matter for serious consideration, and is, in the author's mind, one of the major items in solution of the water problem of Southern California. The mutual company which developed and husbanded its local supply for 60 years and then increased its water costs and used itself as a tax base to bring outside water to develop arid competing land, would certainly be far more than a "good neighbor."

In this regard, consideration should be given to proposals now being discussed to clarify the water code of the state. Figures prepared by the State Division of Water Resources show that of the 4.75 million acres of land now irrigated in California, the source of supply is as follows: 2.50 million acres from underground basins, 1.65 million acres from appropriative surface developments, and 0.60 million acres from purely riparian surface flow.

There is a vast acreage still undeveloped, both riparian and in overlying basins. Much of the latter is now being utilized at or beyond its safe yield and economic limit, and in general there is no unused riparian water. With the constant threat of upstream riparian lands increasing their use to the detriment of downstream users, and a similar threat to established users from underground basins under the doctrine of co-relative rights, a situation of distinct danger to mutual and private irrigation companies is developing. This problem is far too involved to develop here, but it appears that a decision will have to be made, whether to continue the "laissez faire" policy of today, or in some manner to limit new developments encroaching on established usages.

A supply, adequate in quantity for the reasonable needs of Southern California, has been developed and brought to the territory in the past few years. Its early utilization for purposes and on soils for which it is suited is highly desirable. The economic problem can be solved by maintenance of a culture, in this area, capable of supporting long time investments in luxury farm products. The initiative and vision of the men who put their lives into development of an arid semi-desert country to the present garden spot, which is typical of Southern California, must not be lost by the present generation. The political problem is one which is worthy of the best efforts of the entire water works fraternity.

Public ownership of water utilities has come about largely as an economic matter. At its best it is an amplification of the spirit of the men who pioneered in developing the assets of the nation. Certain works are beyond the means of agriculture to underwrite, just as they have been found beyond the means of private capital in nearly every major city in the United States. So long as laws are made by men it seems possible to preserve the heritage of individual initiative and investment and of co-operative enterprise by a slight change in enabling acts which will allow water production and distribution corporations to share in the distribution of additional supplies on a proper financial basis. The problem does not seem insurmountable, and, approached with the objective viewpoint, it should be possible to solve it with a high degree of satisfaction to all concerned.

Summary

In brief, there has been developed in Southern California a culture which is largely the outgrowth of private initiative and co-operative enterprise. Mutual water companies have had a large part in this development. Undue problems of finance, chemistry, and sanitation, have been forced on irrigation companies by the phenomenal "rurbanization" of Southern California. These problems are increasing and the cost trend of irrigation water is on the increase whereas gross and net returns are definitely down. The burden of furnishing return water of adequate quality should be placed on the user who despoils it.

So far as stockholders who use irrigation water from gravity distribution systems for other purposes than that for which the great majority of stockholders use it, there seems to be no recourse except to invest in a domestic system as the others have. There are many means for obtaining a safe supply, but no major irrigation company has found it desirable to sterilize its whole supply for possible intermittent domestic use. The problem is mainly financial and up to the individual.

Regulation of mutual water company rates by any state agency does not exist, but an ever increasing number of the items which comprise cost of delivery are being subjected to law, administrative order, or local direct taxation. Complaints of inadequate service and other grievances on the part of a small percentage of the total number of persons served may lead to some extension of state control

over standards of service and methods of accounting for both mutual and governmental domestic water utilities.

The search for adequate future supply has been made and the development is practically complete. Problems which remain, in regard to its utilization, are mainly economic, chemical, and governmental. The chemical and sanitary problems of domestic and irrigation supply can be solved readily if sound economic conditions are maintained.

The major problem before the mutual corporation, then, is the establishment of a means of co-operating with governmental agencies on equal terms. This problem can be solved and the present culture of the Southwest, which is firmly rooted in co-operative individualism, can be maintained.

Notes on Current Corrosion Problems

By Thomas M. Riddick

SOME of the many pitfalls into which water works men have been thrown in their study of corrosion are the over-emphasis on chemistry (or pseudo-chemistry); too close an adherence to the written word, combined with too great a haste in the publication of new theories and methods; and the failure to heed the opinions of superintendents who have a minimum of technical knowledge but a maximum of good judgment based on long years of experience. These and other factors have thrown the field of corrosion control into such a confusion that it is often difficult to determine the validity of any particular method which suggests itself as a cure for a specific corrosion problem.

A number of superintendents of long experience have been heard to say that their raw reservoir water, before the construction of a filtration plant, was less corrosive than that which obtained with the use of lime treatment and pH control; and, in many instances, their observations in this respect are based on fact. The author has come to believe that, on the whole, the simple pH test has done more harm than good; and he, for one, is willing to admit that certain well waters with from 12 to 20 p.p.m. carbon dioxide and a pH of from 5.6 to 6.2 are less corrosive to distribution mains and household plumbing than some of the alum-treated waters maintained at a pH of 8.0 or above. Some well waters, for instance, are practically saturated with dissolved oxygen, being, in this respect, quite comparable to aerated reservoir or stream supplies, and this fact, confirmed by many analyses, should throw considerable doubt on the value of high hydrogen ion concentration, *per se*, as a major factor in corrosion control.

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Another pitfall has been the attempt arbitrarily to correlate the corrosive qualities of a water with cut sections of distribution mains removed after several years of service. Instead of the corrosive qualities of the water, is it not, *partly*, a function of the solubility or durability of the pitch used to coat the pipe that is indicated? And, with the exception of the recently developed pipe enamels, did not the pitch used for dipping suffer a considerable change, during the last 40 years, as more and more byproducts were extracted?

Any intelligent engineer, chemist, water works operator or superintendent, who has had occasion to observe intimately several different systems, can, without resort to chemical analysis, classify these waters as extremely corrosive, moderately corrosive, slightly corrosive, etc. This conclusion is the result of many separate observations over a long period of time regarding such matters as the decrease in carrying capacity of mains, the time required to flush hydrants to a reasonable clarity, the staining of porcelain and of laundry, the life of hot water boilers, the tuberculation of mains, the life of yellow brass, galvanized steel and wrought iron, the de-zincification of galvanized or yellow brass pipe, the occurrence of red water in the distribution system and dead ends, etc.

Comparative Analyses of Corrosive Waters

Some time ago the author selected about 50 analyses of water from various sources, about which he had some practical knowledge regarding corrosive quality. Many of these samples had been collected from supplies representing both extremes. These samples were then classified into three groups—extremely corrosive, moderately corrosive and non-corrosive—with utter disregard to source or chemical similarity. Every attempt was made to view them statistically, and not from the standpoint of chemistry. Total solids ranged from 20 to 450 p.p.m., alkalinities and hardness from 5 to 300 p.p.m., carbon dioxide from 0 to 40 p.p.m., and pH from 5.5 to 8.6.

This purely practical listing upset much of the beautiful theory of pH control, effect of carbon dioxide and supersaturation of calcium carbonate. It *did* demonstrate one factor that has been lost sight of, i.e., the relationship between alkalinity and hardness, which for many New York State waters is in reality a calcium carbonate to magnesium sulfate ratio. The lower the magnesium sulfate (or non-carbonate hardness), the less corrosive was the water; and the

greater the increase of hardness over alkalinity, the greater was the corrosion. It is not meant to imply that pH has no significance—it does—but what should be pointed out is that, for natural waters which do not receive mineral acid wastes, the test simply expresses the relationship between carbon dioxide and alkalinity, without being a measure of either.

This simple but practical analysis seems to indicate the answer to the many vagaries which still beset the water works chemist. It may well explain why some raw waters are less corrosive than treated ones, regardless of pH, and why soda ash, a soluble carbonate, may be more effective than lime, an hydroxide.

The alkalinity of any raw water is bicarbonate in form. Through coagulation this alkalinity is reduced (according to the dosage), carbon dioxide added and the sulfate content increased. When the original carbon dioxide present, plus that formed by the coagulant, is neutralized with lime, an hydroxide, the original concentration of alkalinity cannot be restored without raising the pH to such an extent that palatability suffers; and, in any event, a sulfate has been substituted for a carbonate by the use of the coagulant. If the alkalinity to hardness ratio of the raw water were, for instance, 3:4, the ratio of the finished water would be 2:4 or less. The use of soda ash, a carbonate, will enable the restoration of the raw water ratio of 3:4, without excessive pH; and, if desired, the ratio can even be raised. As for the calcium carbonate saturation theory, which must be admitted to have merit, can we not supersaturate or partially precipitate calcium carbonate as well with soda ash as with lime, provided, of course, that the alkalinity or hardness of the water is above about 35 or 45 p.p.m.?

Factors in Reduction of Corrosion

It is believed that, from a practical standpoint, which may sometimes be confirmed in theory, those factors tending to *reduce* corrosion are as follows: (1) low non-carbonate hardness, or low sulfate content; (2) high alkalinity; (3) high silica content; (4) low carbon dioxide; (5) low oxygen concentration; and (6) low temperature. Those tending to accelerate corrosion are, of course, the converse of the above.

The last two factors are very important but are generally beyond control. For stream waters, subject to a 40 or 50°F. variation in temperature, however, the corresponding change in dissolved oxygen

has a compensating effect. For well waters which maintain a uniform temperature of 53 to 58°F. throughout the year, oxygen is sometimes subject to control; and it is surprising to find some water works, which have wells low in oxygen (only by Divine favor), spending additional money to construct aerators in elevated tanks, ostensibly for the purpose of reducing carbon dioxide. It is indeed fortunate that these devices do not serve their intended purpose. Carbon dioxide can be easily neutralized by chemicals, but the practical removal of oxygen is not possible in general practice—though Sheppard Powell did accomplish this end for at least one industrial plant. The author, for one, believes that one part of oxygen is as corrosive as two parts of carbon dioxide, and that well waters low in oxygen should never be aerated.

Influence of Silica on Corrosion

The silica content of a water, too, seems to have considerable influence on the rate of corrosion, i.e., the higher the silica, the less the tendency. This point again involves the contention that alum- and lime-treated waters may be more corrosive than raw waters, for coagulation decreases silica content. The examination of a scale film taken from a line protected by "excess precipitated calcium carbonate" or of any scale formation submerged in strong acids, with or without fusing to aid solution, will generally reveal much carbonate, some sulfate, and, almost always, some silica. This also is true of boiler scale. Is not this an indication that silica plays a role in the formation of protective coatings? Sodium silicate has been used for corrosion control, but, in most instances, the alkalinity, carbon dioxide and sulfate content have been disregarded.

One more phase of silica as a factor in corrosion merits attention. Few superintendents or chemists who collect samples from dead ends fail occasionally to find that the water has a turbidity with a distinctly "bluish" cast, though the color is often masked by the conventional brown of ferric oxide. This colloidal precipitate cannot be filtered, and, from a practical standpoint, cannot be brought down by centrifuging. It is insoluble in all acids *except* hydrofluoric, and it has the same pale cast which is characteristic of dilute, partially neutralized solutions of sodium silicate. Whether this precipitate is silica, and, if it is, why it should be forced out of solution is a problem that deserves much further consideration, since its answer will no doubt throw considerable light on scale formation.

Treatment of an Unusual Water

Returning to the general subject of corrosion and its control, however, the author would like to cite one instance involving a rather interesting water, for an estate, which he undertook to treat. The water had a carbon dioxide content of about 40 p.p.m., an alkalinity of 9 p.p.m., a pH of 5.5 and a hardness of 60 p.p.m. Corrosion of cast iron, galvanized steel and yellow brass was severe. In many lines the yellow brass was completely de-zincified, and the spongy copper could be cut with a knife.

To neutralize the carbon dioxide completely required such a large dosage of soda ash as to impart a definitely flat, "sodium bicarbonate" taste. If sodium hydroxide was used, the alkalinity would not have been raised sufficiently. Therefore, a compromise treatment of 50 per cent caustic and 50 per cent soda ash was selected.

After two years of this treatment, there has been no evidence of further corrosion. The iron content at residence taps dropped from about 1 or 2 p.p.m. to zero, and the copper, which was formerly sufficient to impart a green stain to laundered goods, has been entirely eliminated. It is believed that lime would not have proved as effective in this instance.

In closing, the author would like to reiterate his belief that much of the confusion that exists in the field of corrosion control at present results directly from the too ready acceptance of unproved theories and methods. His own opinions expressed here are based upon over a thousand chemical analyses, but they, too, need substantiation before they can be cited as true precepts. What they *should* indicate, however, is that many of the practices already adopted as standard are really far from valid, established procedures.

Notes on Current Flocculation Problems

By Thomas M. Riddick

FLOCCULATION has been studied for many years, but the fact remains that there is still a wide discrepancy between theory, i.e., laboratory experiment, and practice. There is a definite reason for such divergence, it being the lack of any suitable test for evaluating the "toughness" or "filtrability" of floc particles. The size of particle has received some consideration, but any practical operator can testify that the "size of floc" can be judged more accurately by visualization—in either mixing basin or laboratory beaker—than by measuring individual particles under the microscope.

It may be asked if weak flocculation does occur at times and if alum, when it is used as a coagulant, does pass the filter at certain seasons. The answers to these questions must depend upon the honesty or the diligence of the operator, but it is the author's firm conviction that both are to be answered in the affirmative, and the proof of that reply is certainly evident from the fact that when either clear-water basins or storage reservoirs are cleaned, a sizable amount of precipitated aluminum hydroxide, or sludge, is found. Where activated carbon is used, it, too, may pass the filter during weak coagulation as is sometimes visually evident upon hydrant flushing, particularly at dead ends. In this observation, the author wishes to emphasize the fact that he is not confusing carbon with the black magnetic iron oxide which is formed when corrosion is sufficiently severe to deplete the dissolved oxygen completely. The two may be differentiated easily by placing some of the pulverized dried sludge (obtained by settling out the "black water" from the flushed hydrant) on a piece of paper and oscillating a horseshoe magnet

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underneath. Magnetic iron oxide is strongly attracted whereas carbon remains in place.

The operator who does not admit weak flocculation is either extremely naive or does not collect frequent samples of the filter and plant effluents, unless, of course, his reservoir is sufficiently large to exert a homogenizing and stabilizing action on the raw water from year to year.

At several water works, pilot plants, consisting of three 3-gallon clear glass jars into which are continuously discharged the raw, treated, and finished waters respectively, have been erected in the laboratory or office for continuous visual control. The jars have a white and black striped porcelain background, highly illuminated by fluorescent lamps, and the treated water receives continuous agitation to produce floc formation comparable to that obtained in the mixing basin.

The finished water jar gives the operator a far better conception of the efficiency of his filters in removing floc and silt than can be obtained by any reasonable number of turbidity tests. If filters are properly graded, if the sand is properly sized and is uncoated, and if the floc particles are "tough" and "well formed," the plant effluent should have a clarity approaching, if not equaling, that of distilled water. In regard to turbidity, it may be indicated also that a two-liter beaker, freshly washed with caustic to remove grease and film and to lower surface tension, serves as well as the best commercial turbidimeter on the market.

Silica as a Factor in Weak Flocculation

"Weak flocculation," or "tender floc," generally occurs in the fall or winter months. In the past it has been the practice to attribute this condition to the presence of "organic acids leached from decaying vegetation." A sorrier excuse was never perpetrated; and it remained for Baylis, somewhat accidentally, to hit upon what the author agrees is the real cause, i.e. low silica content of the raw water, or the presence of silica in such a state that it is not available for reacting with the coagulant to form a "tough" floc.

The theoretical aspects of the role which silica plays are still vague. It is known that if sodium silicate is properly diluted, neutralized to an alkalinity of approximately 1,200 p.p.m., aged for several hours, and applied to the raw water at dosages from 4 to 8 p.p.m., floc particles are increased in size and are definitely "toughened"; and

it is the degree of "toughness," which cannot be measured in numerical or mathematical terms, that is *most* important. If sodium silicate is added without the proper neutralization of excess alkali, not only does coagulation fail to improve, but it is definitely inhibited. Similarly, quartz, ground to the consistency of wheat flour, will not give any material aid.

Why some waters dissolve more silica than others, and why the concentration of "available silica" fluctuates are problems which are as yet indeterminate, but, no doubt, the major factors are carbon dioxide, amount of quartz or sand on the watershed, size of sand particles, period of ground water retention and temperature. For well waters, the period of retention, which is a function of pumping, and yield of watershed, seem most important. For stream waters, temperature apparently has a marked effect. When the ground is frozen to a depth of several feet for a long period of time, without intermittent thawing, the silica content may gradually decrease; and when this drops, e.g., from 8 or 9 to 4 or 5 p.p.m., weak floc formation inevitably occurs. On several occasions weak coagulation has been predicted long in advance of its occurrence by the observation of diminishing silica.

Experience With Weak Flocculation

An extreme example of the effects of low silica is a recent experience at the Nyack, N. Y., filtration plant where the normal content of the raw stream water is 6 to 9 p.p.m. and where general observation indicates that the higher the silica the tougher the floc. Over a period of several weeks, silicon dioxide dropped to 4 or 5 p.p.m., though floc particles formed slowly and the size was fairly large. A velocity of $\frac{3}{4}$ ft. per sec., which is much slower than obtains at most plants, through the outlet ports of the sedimentation basin and through the filter inlet valves (shear gates in this instance), however, was sufficient to disintegrate or peptize the floc completely, with the result that alum would pass the filter an hour after backwashing and that the filter effluent would be quite turbid after 6 to 8 hr. Laboratory jar tests showed little or no improvement in toughness by using ferric chloride, ferric sulfate, sodium aluminate, Bentonite, chlorine (pre-chlorination), or combinations of these coagulants. An improvement was definite upon the addition of about 5 p.p.m. of sodium silicate (as SiO_2), though no provision was available for its proper

application and though this treatment cannot ordinarily be used in a haphazard way with makeshift equipment. In this emergency, alum and carbon were entirely eliminated and the water was simply filtered and chlorinated.

In this respect, the author believes that it is preferable to produce a water with a color of 10 to 15 p.p.m., containing some turbidity, than to discharge alum into the system, where it will give trouble at a later time. To have denied or ignored the presence of aluminum hydroxide in the case cited would have been wishful thinking, since it was visually evident as a finely divided turbidity which precipitated when stored in sample bottles overnight.

Why a silica content of 7 to 10 p.p.m. is effective, whereas one of 4 to 5 p.p.m. fails to give appreciable aid, is a question as yet unanswered. It may be that a certain concentration or potential is necessary; it may be that the silica is in such a molecular state that it is not available, as is true of ammonia (or what the Nessler test differentiates as ammonia) in swimming pool waters; or it may be that the molybdate test is considerably in error. In any event the accuracy of this analysis on raw colored waters is at best not greater than plus or minus 1 to 2 p.p.m.; and on finished samples *without* color it is far from exact.

Effect of Turbidity on Coagulation

Another well known factor affecting coagulation is turbidity of the raw water. In this respect it may be pointed out that, within limits, the greater the turbidity, the better the flocculation. Plant experiments are now under way in which a portion ($\frac{1}{2}$ to 1 per cent) of precipitated sludge is returned to the raw water. Due to the use of carbon, the sludge is "sweet," and it is predicted that the treatment will prove very effective if proper equipment for collecting fresh sludge is installed in sedimentation basins. This floc is "tough," will not readily disintegrate or peptize, produces ample turbidity, factors in which the silica content of the precipitated sludge, no doubt, plays an important role.

At the Ossining, N. Y., plant, silica has been applied for about six weeks and results to date (March, 1941) are most promising. Filter runs are greatly extended due to better sedimentation, and floc particles were tough during the period of extremely weak flocculation at the Nyack plant.

The practical application of silica, however, has its operating kinks. It was only after gelling (to a firmness exceeding nutrient agar) several 150-gallon crocks that it was found that the stoichometric relationship between excess sodium oxide and sulfuric acid is considerably in error unless the dilution factor is taken into consideration. Another very interesting fact is that silica is of little or no aid unless the raw water has a turbidity of 5 to 10 p.p.m., or unless floc has begun to form in the mixing basin. After a shutdown over the week-end, during which period all floc subsides, the silicate feeder cannot be cut in until after about an hour of operation using alum only, for although silica is an asset after floc has formed, it can be just as great a deterrent if it is applied before suspended matter is present.

Further practical plant research on coagulation is necessary so that we may arrive at a more logical and truer understanding of this most important factor in the operation of rapid sand filtration plants. It is expected that such work will be of great practical benefit in solving many of the problems of filtration which now are caused by the lack of a properly conditioned influent.

Bacteriological Quality of Water From Small Filtration Plants Treating Surface Waters

By Herbert Bosch and Abel Wolman

SATISFACTORY operation of water purification plants serving small municipalities presents numerous problems to the state health official who must exercise general supervision over the quality of the water produced by such plants. In the small municipality of a population of 5,000 or less, it is rather difficult to persuade the local officials that technically trained water plant operators are necessary, and, as a result, these small plants are very frequently operated by a personnel which has had no technical training. Most state health departments give a considerable amount of assistance to such plants, but, unfortunately, the health departments in most states do not have a sufficient personnel in their sanitary engineering divisions to permit continuous close supervision of all the water plants in the state. Gorman and Wolman (1) showed that, in the period 1920–36, 66.6 per cent of the water-borne outbreaks of typhoid fever in the United States occurred in cities having populations under 5,000. They point out that the communities in this group are "deserving of special attention by public health and water works officials."

Because the operation of small water purification plants presents peculiar problems, many health authorities have favored the installation of ground water supplies in those small municipalities where it is possible to obtain such a supply that is both adequate and bacteriologically satisfactory. In many small towns, however, the supply of ground water is inadequate or of unsatisfactory chemical quality; and in such communities, if there is to be a public water

A contribution by Herbert Bosch, Public Health Engineer, Division of Sanitation, Minnesota Department of Health, Minneapolis, Minn., and Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.

system, it is necessary to use surface water as a source of supply and to provide a water purification plant designed to treat such water.

In order to secure data on the results obtained at water purification plants operated by non-technical personnel and serving communities of populations of less than 5,000, the bacteriological records of four small plants situated in an eastern state (State A) were studied in detail and the records of 39 plants in a midwestern state (State B) were summarized.

State A

The four plants which were studied are visited at intervals of from one to two months by engineers of the Bureau of Sanitary Engineering of the State Health Department. For comparison, the bacteriological data from a large plant in the same state, which is operated by a technically trained personnel, were also summarized.

Source of Bacteriological Data

Through the courtesy of the chief engineer and the principal assistant sanitary engineer, bacteriological and other data pertaining to these plants, in the files of the Bureau of Sanitary Engineering, were made available for this study. All the bacteriological data are based on samples collected and analyzed by the personnel of the State Health Department. The samples were shipped in iced containers to the Department laboratory. A few of the samples collected in 1940 from plant No. 5 were treated with sodium thiosulfate to neutralize any residual chlorine present, but in all the other samples, herein referred to, residual chlorine, when present, was not neutralized at the time the samples were collected.

The State Health Department laboratory procedure in all coliform determinations is to analyze five 10-ml. portions of all samples, and to set up single decimal portions ranging from 1 ml. to dilutions expected to be negative for members of the coliform group. It should be noted that it is the routine procedure of the Department to analyze portions of 1.0, 0.1 and 0.01 ml. on tap samples, even though it is extremely rare to find coliform organisms in portions smaller than 10 ml. The value of this procedure was apparent in several instances in which all five 10-ml. portions were positive. In this study all coliform densities are expressed in terms of most probable numbers (M.P.N.) per 100 ml.

Brief Description of Plants

Plant No. 1: The source of this supply is an interstate river which is subject to considerable sewage pollution, and which, at times, becomes quite turbid. The water purification plant was installed in 1905. It consists of a raw water pump; a coagulation basin, which provides a detention period of approximately 40 min.; two wood-stave filters, which are operated at about half their rated capacity; a filtered water collecting basin; and high service pumps. Alum is used as a coagulant and is fed into the suction of the low service pumps at a dosage of $\frac{1}{2}$ to $1\frac{1}{2}$ g.p.g. Lime is fed into the suction of the high service pump at a dosage of $\frac{1}{4}$ to $\frac{1}{2}$ g.p.g. in order to raise the pH of the filtered water. Disinfection is accomplished by means of liquid chlorine applied to the filtered water. Only one chlorine machine is available. The distribution system includes an uncovered reservoir. The only chemical determination made is the residual chlorine test; and an effort is made to maintain a residual chlorine content of 0.2 p.p.m. after a 5-minute absorption period. In some instances in the past, when chlorinous tastes were present in the water, a local municipal official ordered the operator to reduce the chlorine dosage.

Plant No. 2: The source of this supply is a small reservoir which impounds the water from a stream having a drainage area of less than 2 sq.mi. The turbidity of the raw water changes rapidly, ranging between 20 and 1,000. The water purification plant was constructed in 1915, and improvements were made in 1932. The purification plant includes a mixing chamber; a coagulation basin, which provides an average detention period of between 2 and $2\frac{1}{2}$ hr.; two rapid sand filters; and a filtered water collection basin. Alum and lime are used as coagulants. Chlorine for disinfection is fed into the filtered water collection basin. Only one chlorine machine is provided at the plant. The distribution system includes a standpipe and an elevated tank. Chemical determinations made by the operator include tests for residual chlorine, pH, and turbidity.

Plant No. 3: The source of this supply is a creek whose drainage area consists of agricultural land. A low dam provides a small reservoir for the raw water. The purification plant was constructed in 1925. It consists of a coagulation basin, which provides a detention period of approximately 1 hr.; two rapid sand filters; and a filtered water collection basin. Alum for coagulation is applied in

the suction of the raw water pump; and lime for pH control is applied to the filter effluent. Chlorine is applied in the suction of the high service pumps. Only one chlorinator is provided. Until September, 1938, the distribution system included an uncovered surface reservoir. In that year, this reservoir was abandoned, and a new covered one constructed. The original operator of the plant died in 1934 and was succeeded by his son. The plant was out of service for several days in 1936, and again in 1937, because of flood conditions. In both instances the State Health Department took immediate precautionary steps to safeguard the supply before the plant was put back into service. Chemical tests made by the operator include residual chlorine, coagulation, and turbidity determinations.

Plant No. 4: Water for this plant is derived from a surface source, and from an underground source. The surface source, a small stream whose drainage area is agricultural land, supplies about 40 per cent of the total water pumped. Water from this source is treated in a purification plant which was constructed in 1921. The plant includes a mixing chamber, into which alum is applied; a coagulation basin, which provides a detention period of 2 hr.; two rapid sand filters; and a filtered water collection basin. When the filtration plant was constructed in 1921, a heavy flow of ground water was encountered in the excavation for the filtered water reservoir. This spring still enters the filtered water collection basin, and furnishes about 60 per cent of the water used by the municipality. Liquid chlorine for disinfection is applied in the suction of the high service pumps. The distribution system includes an uncovered surface reservoir.

Plant No. 5: The data on this plant are included for purposes of comparison, since it is a large plant operated under laboratory control. The source of the supply is a small impounding reservoir, the water from which varies widely in turbidity. The purification plant includes an aerator; a primary settling basin, which has a normal detention period of 4 hr.; coagulation basins, which provide approximately a 1-hour detention period; rapid sand filters; and a filtered water reservoir. Coagulants may be applied either at the entrance of the primary settling basin or at the entrance of the coagulating basins. The filtered water is disinfected with liquid chlorine. Daily bacteriological analyses are made at the plant. In order to give closer comparability with the small plants, however, the bacteriological data in this paper are based only on analyses made by the State Department of Health.

Raw Water Coliform Densities

Table 1 gives data on the coliform densities of the raw water at plants No. 1, 2, 3 and 5. Data on the raw water at plant No. 4 are not included since only 14 raw water samples were collected from 1930 to 1939. Of these 14 samples, the M.P.N. per 100 ml. for one sample was 24,000 and for the other thirteen samples, 2,400 or less. In the same period, only 12 samples were collected from the spring which flows into the filtered water collecting reservoir. Ten of these samples gave negative results in all of the 10 ml. and smaller portions tested. One sample had a M.P.N. of 38 per 100 ml. and one, 2.2 per 100 ml.

TABLE 1

Percentage of Total Raw Water Samples Giving Coliform Densities Equal to or Exceeding Specified Values—State A

PLANT NO.	PERIOD	MEAN COLIFORM DENSITY PER 100 ML.	NUMBER OF SAMPLES	SAMPLES GIVING COLIFORM DENSITIES (M.P.N. PER 100 ML.) EQUAL TO OR EXCEEDING:					
				2.2	38	240	2,400	24,000	240,000
		M.P.N.		%	%	%	%	%	%
1	1929–39	15,150	57	98.2	96.5	84.2	59.6	26.3	3.5
2	1929–39	3,150	79	88.6	65.8	48.1	26.6	13.9	—
3	2/11/20–2/28/40	2,950	140	90.0	77.1	56.4	22.9	10.7	—
5	1/ 1/35–4/ 6/40	5,800	301	99.0	89.7	74.7	41.9	19.6	—

The data given in Table 1 are plotted on Hazen's logarithmic probability paper in Fig. 1. Also indicated in the figure are the M.P.N. values corresponding to coliform indices (Phelps) of 5,000 and 3,300, determined by Streeter (2) to be the maximum permissible raw water concentrations under which average Ohio River and Great Lakes filtration plants, respectively, are able to produce chlorinated effluents which comply with the primary requirements of the U. S. Treasury Department standard. Wolman (3) in Maryland, and Streeter (2) in his extensive studies of Ohio River plants, observed that both the 24-hour bacterial count at 37°C. and the coliform index, when plotted on this type of paper, gave plots having definite straight line trends which indicated that the bacterial concentration of the several raw waters had a tendency to form "normal" frequency distributions when converted to their logarithmic functions. It will be noted that even though there were only a relatively small number of samples,

there is also a definite straight line trend in the plots for all the plants shown in Fig. 1.

On the basis of the data given in Table 1 and Fig. 1, it is seen that plants No. 2 and 3 had the lowest raw water coliform densities, plant No. 1 had the highest raw water coliform density, and plant No. 5 occupied an intermediate position.

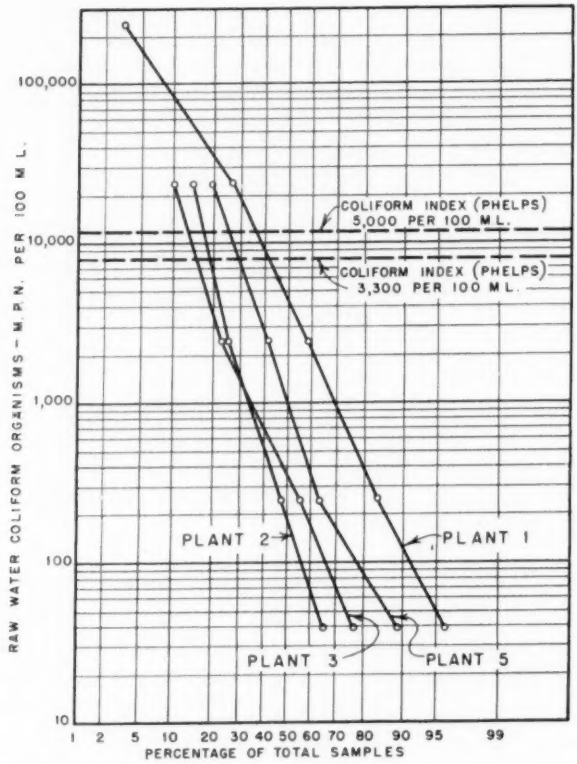

FIG. 1. Logarithmic Probability Plot; showing frequencies with which raw water coliform densities (M.P.N. per 100 ml.) of State A Plants equaled or exceeded specified values

Tap Water Coliform Densities

Tables 2 and 3 summarize the results of the determination of coliform organisms in tap samples. It should be pointed out that the tap samples, many of which were collected from taps at locations other than at the filtration plants, are, possibly, not entirely repre-

sentative of the water produced by the purification processes. It would, of course, be possible for a water to be free of coliform organisms as it leaves the plant, and for it to be contaminated subsequently in the distribution system. The tap samples do, however, indicate the bacteriological quality of the water delivered to the consumers, and they are probably fairly representative of the water leaving the plant.

It will be noted from Table 3 that the tap samples from plants No. 1, 3 and 4 failed to comply consistently with the U. S. Treasury Department standard and that those from plants No. 2 and the control plant, No. 5, were well within this standard. It will also be evident that for the individual years 1930–33 inclusive, plant No. 3

TABLE 2

Percentage of Total Tap Samples Giving Coliform Densities Equal to or Exceeding Specified Values—State A, 1930–39

PLANT NO.	NUMBER OF SAMPLES	SAMPLES GIVING COLIFORM DENSITIES (M.P.N. PER 100 ML.) EQUAL TO OR EXCEEDING:						
		2.2	5	8.9	15	38	240	2,400
		%	%	%	%	%	%	%
1	117	10.25	9.40	7.69	6.83	5.12	2.56	2.56
2	99	2.02	0	0	0	0	0	0
3	98	21.44	21.44	18.36	14.28	8.16	4.08	0
4	135	13.33	10.36	8.88	8.88	7.40	5.92	1.48
5*	312	7.05	2.25	1.61	0.64	0.32	0	0

* For period 1/1/35–4/6/40.

complied with the standard, though not by a very wide margin. In 1934, the original plant operator died, and another operator assumed charge of the plant. From a bacteriological standpoint, the quality of the tap water was poorest during that year. This perhaps points to a problem which is peculiar to small plants, and which arises when an operator dies, resigns, becomes ill, or takes a vacation.

Table 2 shows the frequencies with which the coliform densities equaled or exceeded certain values. The significant feature of this tabulation is the fact that three of the plants, Nos. 1, 3 and 4, occasionally had tap samples with M.P.N. values of 240 per 100 ml., and that values of 2,400 per 100 ml. were indicated in three samples from plant No. 1 and in two samples from plant No. 4. In contrast, the maximum M.P.N. values in tap samples from plants No. 2 and

TABLE 3

Results of Analyses of Tap Samples for Coliform Organisms With Respect to Compliance With the Treasury Department Standard—State A, 1930–39

YEAR	NUMBER OF SAMPLES	NUMBER OF 10-ML. TUBES	POSITIVE 10-ML. TUBES		SAMPLES WITH THREE OR MORE POSITIVE TUBES		COMPLIANCE WITH TREASURY DEPARTMENT STANDARD
			No.	*%*	*No.*	*%*	
Plant No. 1							
1930	7	35	0	0	0	—	Yes
1931	10	50	10	20	2	—	No
1932	8	40	0	0	0	—	Yes
1933	12	60	5	8.3	1	—	Yes
1934	13	65	13	20	2	—	No
1935	12	60	7	11.7	1	—	No
1936	21	105	0	0	0	—	Yes
1937	11	55	0	0	0	—	Yes
1938	11	55	0	0	0	—	Yes
1939	12	60	12	20	3	—	No
Totals	117	585	47	8.0	9	7.7	
Plant No. 2							
1930	9	45	0	0	0	—	Yes
1931	10	50	1	2.0	0	—	Yes
1932	9	45	1	2.2	0	—	Yes
1933	10	50	0	0	0	—	Yes
1934	9	45	0	0	0	—	Yes
1935	12	60	0	0	0	—	Yes
1936	10	50	0	0	0	—	Yes
1937	8	40	0	0	0	—	Yes
1938	10	50	0	0	0	—	Yes
1939	12	60	0	0	0	—	Yes
Totals	99	495	2	0.4	0	0	
Plant No. 3							
1930	12	60	6	10.0	1	—	Yes
1931	10	50	0	0	0	—	Yes
1932	9	45	3	6.7	1	—	Yes
1933	10	50	4	8.0	1	—	Yes
1934	12	60	27	45.0	6	—	No
1935	10	50	14	28.0	2	—	No
1936	12	60	12	20.0	3	—	No
1937	7	35	5	14.3	1	—	No
1938	8	40	5	12.5	1	—	No
1939	8	40	7	17.5	2	—	No
Totals	98	490	83	16.9	18	18.4	

TABLE 3—*Concluded*

YEAR	NUMBER OF SAMPLES	NUMBER OF 10-ML. TUBES	POSITIVE 10-ML. TUBES		SAMPLES WITH THREE OR MORE POSITIVE TUBES		COMPLIANCE WITH TREASURY DEPARTMENT STANDARD
Plant No. 4							
			No.	%	*No.*	%	
1930	8	40	15	37.5	3	—	No
1931	9	45	0	0	0	—	Yes
1932	16	80	5	6.2	1	—	Yes
1933	14	70	1	1.4	0	—	Yes
1934	20	100	5	5.0	1	5.0	Yes
1935	12	60	2	3.3	0	—	Yes
1936	18	90	21	23.4	4	—	No
1937	11	55	0	0	0	—	Yes
1938	13	65	5	7.7	1	—	Yes
1939	14	70	12	17.2	2	—	No
Totals.....	135	675	66	9.8	12	8.9	
Plant No. 5 (1/1/35-4/6/40)							
Total.....	312	1560	37	2.3	5	1.6	Yes

5 were 2.2 and 38 per 100 ml., respectively. The fact that these high coliform densities (240 per 100 ml. or over) occurred in three samples from plant No. 1, in four samples from plant No. 3, and in eight samples from plant No. 4, makes it extremely unlikely that they were occasioned by faulty collection of samples or by laboratory errors. From the standpoint of potential possibility of transmission of waterborne diseases, very high coliform concentration in the tap samples for only a few days in the year may be of considerably more importance than the average bacterial quality of the water.

State B

Since the study of the data from the four small plants situated in State A indicated that three of the plants did not consistently produce water which complied with the Treasury standard, the results from 39 plants situated in a midwestern state were summarized for the years 1937, 1938 and 1939. These 39 plants represent all of the filtration plants in that state which serve municipalities having populations of less than 5,000 and which treat surface waters. In general, these plants are of more recent construction, treat more turbid

TABLE 4

Results of Analyses of Tap Samples for Coliform Organisms With Respect to Compliance With the Treasury Department Standard—State B, 1927–39

(Plants listed in order of percentage of positive 10-ml. tubes)

PLANT NO.	NO. OF SAMPLES	NO. OF 10-ML. TUBES	POSITIVE 10-ML. TUBES		SAMPLES WITH THREE OR MORE POSITIVE 10-ML. TUBES		COMPLIANCE WITH TREASURY DEPARTMENT STANDARD		
							1937	1938	1939
			No.	%	*No.*	%			
1	350	1,750	2	0.1	0	0.0	Yes	Yes	Yes
2	471	2,355	7	0.3	0	0.0	"	"	"
3	308	1,540	8	0.5	0	0.0	"	"	"
4	333	1,665	9	0.5	1	0.3	"	"	"
5	367	1,835	11	0.6	0	0.0	"	"	"
6	251	1,255	9	0.7	0	0.0	"	"	"
7	413	2,065	14	0.7	2	0.5	"	"	"
8	318	1,590	20	1.3	1	0.3	"	"	"
9	371	1,855	24	1.3	1	0.3	"	"	"
10	516	2,580	35	1.4	5	1.0	"	"	"
11	464	2,320	32	1.4	2	0.4	"	"	"
12	483	2,415	33	1.4	5	1.0	"	"	"
13	513	2,565	38	1.5	9	1.8	"	"	"
14	356	1,780	29	1.6	3	0.8	"	"	"
15	510	2,550	42	1.6	4	0.8	"	"	"
16	432	2,160	35	1.6	4	0.9	"	"	"
17	518	2,590	41	1.6	6	1.2	"	"	"
18	479	2,395	39	1.6	6	1.3	"	"	"
19	494	2,470	41	1.7	5	1.0	"	"	"
20	430	2,150	41	1.9	4	0.9	"	"	"
21	215	1,075	22	2.0	3	1.4	No	"	"
22	516	2,580	54	2.1	6	1.2	Yes	"	"
23	324	1,620	37	2.3	5	1.5	No	"	"
24	541	2,705	73	2.7	12	2.2	"	"	"
25	401	2,005	60	3.0	9	2.2	Yes	"	"
26	471	2,355	69	3.0	11	2.3	"	"	"
27	492	2,460	85	3.5	12	2.4	"	"	"
28	418	2,090	75	3.6	10	2.4	"	"	"
29	300	1,500	55	3.7	7	2.3	"	"	"
30	519	2,595	99	3.8	16	3.1	No	"	"
31	147	735	28	3.8	4	2.7	Yes	No	"
32	450	2,250	88	3.9	9	2.0	"	Yes	"
33	569	2,845	150	4.2	28	4.9	No	"	"
34	355	1,775	86	4.8	14	3.9	"	"	"
35	338	1,690	83	4.9	8	2.4	"	"	"
36	321	1,605	131	8.2	25	7.8	Yes	No	No
37	185	925	91	9.8	14	7.6	"	Yes	"
38	282	1,410	145	10.3	25	8.9	No	No	"
39	400	2,000	221	11.1	36	9.0	"	Yes	Yes
Totals.....	15,621	78,105	2,162	2.77	312	2.0			

waters and have coagulation basins which provide longer detention periods than the four plants in State A.

Source of Bacteriological Data

The bacteriological and other data on these plants were made available through the courtesy of the Chief Public Health Engineer of the State Health Department. In this state, the plant operator ordinarily collects one series of samples each week and these samples are analyzed by the State Health Department laboratories. Residual chlorine, if present in the samples, is not neutralized at the time of collection. The procedure of the State Health Department is to inoculate only five 10-ml. portions of each sample. Samples are not iced in shipment to the laboratories. It will be noted that in several respects, particularly since the samples are collected by the plant operators rather than by representatives of the State Health Department, these results are not entirely comparable to those collected in State A.

Bacteriological Quality of Tap Samples

Table 4 gives the results of the coliform determinations on tap samples from these plants. The results are tabulated with respect to the bacteriological requirements of the Treasury Department standard, and, in the tabulation, the plants are arranged in order of the percentage of 10-ml. tubes which were positive. It will be noted that 12 of the 39 plants (30.8 per cent) failed to comply with the Treasury Department standard in at least one of the three years (one plant failed to comply in two of the three years, and one did not comply in any of the three years).

Data were not available on the maximum coliform concentrations in the tap samples. It is of interest, however, that 2.0 per cent of all the tap samples had three or more positive 10-ml. portions out of the five standard portions. Reed (4) has shown that with an average coliform density of 1.05 per 100 ml., this should not occur in more than 0.856 per cent of the samples. Over the course of the three-year period, only 12 of the 39 plants (30.8 per cent) had 0.856 per cent or less of standard samples with three or more positive portions.

Compliance with the Treasury Department Standard among the 39 plants was as follows: in 1937, 30 complied; in 1938, 36; and in 1939, 36. Based on this compliance with the Treasury Department standard by the individual plants, the bacteriological results for the

year 1937 were the poorest. In this respect, it is pertinent to note that this state began to establish district health units in 1937 and that all areas in the state are now served by such district units. Included in the personnel of each of these units is a public health engineer. While it is impossible to determine just how much of the improvement in the bacteriological quality of these water supplies in 1938 and 1939 was due to the supervisory activities of the district public health engineers, it is reasonable to assume that some of it may be attributed to their work.

Summary and Conclusions

1. The bacteriological records of four small water purification plants in an eastern state (State A) over a period of ten years, and of 39 small water purification plants in a midwestern state (State B) over a period of three years were studied. A large plant situated in State A and operated under technical supervision was studied as a control.

2. In State A, three of the four small plants failed to produce water which consistently complied with the U. S. Treasury Department bacteriological standard. The fourth had an excellent bacteriological record over the ten-year period. The bacteriological results on tap samples from the control plant were well within the limits set by the Treasury Department standard. In State B, 12 of the 39 plants, or 30.8 per cent, failed to comply with the bacteriological requirements of the U. S. Treasury Department standard in at least one of the three years covered by the study.

These data indicate that the operation of small water purification plants is still a major problem. The failure of a large number of small water purification plants to comply with the existing Treasury Department standard as to bacteriological quality is particularly significant in view of the current discussion as to the advisability of making the provisions of this standard more stringent.

3. Tap samples from the four small plants in State A showed maximum coliform concentrations, expressed as M.P.N. per 100 ml., of 2,400, 2,400, 240 and 2.2, respectively. No data were available on the maximum coliform concentrations in the tap samples from plants in State B. Of all the standard samples, however, 2.0 per cent had three or more positive 10-ml. portions. This suggests that occasional lapses in the operation of small plants may result in water of very questionable quality being placed in the distribution system.

From the standpoint of potential transmission of water-borne diseases, very high coliform concentrations in the tap samples for only a few days in the year may be of much more importance than the average bacterial quality of the water.

4. The bacteriological result from one plant (No. 3 in State A) demonstrates an administrative problem which is peculiar to small plants and which may arise when an operator dies, resigns, becomes ill or takes a vacation. At this plant a change in operators was accompanied by a marked deterioration in the bacterial quality of the tap water samples over a period of several years.

5. In State B, improvement in the bacteriological quality of the tap water samples occurred after district health units, each of whose personnel includes a public health engineer, were established in all sections of the state. It cannot be stated how much of this improvement was due to the efforts of these district public health engineers; but it is reasonable to assume that at least a portion of it was.

The more liberal use, in district and county health units, of public health engineers who are trained in the science of water purification may offer one method of improving appreciably the operation of small water purification plants.

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Clogging of Rapid Sand Filters

By Rolf Eliassen

THE ultimate object of investigators in the field of water filtration is to develop a complete theory which will correlate all of the variables affecting the clogging of a rapid sand filter. When and if such a theory is developed, the engineer designing a filter plant will be able to predict the performance of the filter when using different depths of sand layers, various sizes and gradations of sand, selected rates of filtration, and certain characteristics of flocculated matter. Knowing the results which will be obtained with different combinations of these variables, he may determine the combination of factors which will give the most economical and efficient treatment of the water.

Over the past five decades, many investigators have undertaken studies of the performance of rapid sand filters. These have dealt mostly with the entire filter layer as a unit and have not attempted to observe the phenomena taking place in successive depths of the sand layer. Exceptions to this include the experiments undertaken at Baltimore and Toronto and reported by the A.S.C.E. Committee of the Sanitary Engineering Division on Filtering Materials for Water and Sewage Works (1). These tests involved the measurements of the amount of accumulated turbidity at various depths of the filter at the end of specified runs. They made no attempt, however, to measure the rate of removal of turbidity at these depths. A knowledge of the changes taking place as they occur in the filter is as important as, if not more important than, the total changes which have occurred after a period of time. Both are necessary for a more complete understanding of the action of a rapid sand filter.

Experiments conducted by the author, and reported here in part, have considered an important phase of the problem of filtration.

A contribution by Rolf Eliassen, Associate Professor of Sanitary Engineering, New York University, New York City. The major portion of the research reported here was undertaken by the author as the recipient of the Austin Research Fellowship at the Massachusetts Institute of Technology.

Particular attention has been devoted to the time rate of removal of solid matter from the water by the sand, at different layers in the filters, and to the variation in this removal throughout the length of the run. The time rate of increase of lost head, caused by the removal of solids, has also been studied. A knowledge of the time rate of clogging, the amount of matter removed per unit of depth, and the rate of increase of lost head accompanying this clogging are essential for the development of a complete theory of filtration.

No attempt has been made in these studies to determine the relative importance of the different theories of actual removal of solid matter by the sand grains, i.e. mechanical straining, sedimentation, adsorption, adhesion, and biological agencies. Study has been limited to the collective results of these actions, to wit, the clogging of a rapid sand filter.

This research has indicated that, among the factors which may influence the depth to which coagulated matter will penetrate, the rate per unit time at which it will be removed in various layers and the time rate of increase of lost head are the following:

1. Size of sand grains
2. Shape of sand grains
3. Variation of sand size with depth
4. Character of flocculated matter
5. Concentration of flocculated matter
6. Amount of flocculated matter already in the layer at each depth
7. Rate of filtration
8. Temperature of water
9. Porosity of filter layer
10. Consolidation of the layer during the run

Filtration Apparatus

Most of the experiments were performed on an experimental filter (Fig. 1) located in the pump room of the Providence, R. I., filtration plant. The filter was rectangular in cross-section, having a surface area of 2.02 sq.ft. Three sides were constructed of metal and one of glass. The sand was supported by a porous plate, which also served to distribute the wash water. The layout of the auxiliary equipment is indicated in Fig. 2. It was possible to maintain a constant pressure on the filter by means of the constant-level tank. A constant rate of filtration was obtained through the use of a butterfly valve type

of rate controller. Influent water was obtained by means of a screw pump taking water from the settled water conduit going to the plant filters. The wash water was supplied from the plant's wash water tank.

Piezometer tubes were provided in the filter and spaced as shown in Fig. 2. They may also be seen projecting at the left of the filter in Fig. 1. By connecting each of these piezometer tubes to one of the

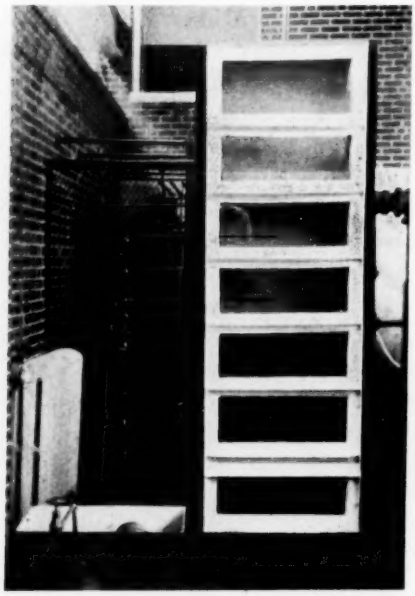

FIG. 1. Experimental Filter at Providence, R. I., Filtration Plant; showing piezometer tubes projecting at left

manometer tubes, the pressure at each of these points in the filter could be determined. These tubes were also used for sampling the water.

Properties of Sand

The sand used at Providence was white silica sand from Ottawa, Ill. Sieve analyses were made using Tyler standard sieves and a 20-minute sieving period in a Ro-Tap mechanical shaker. The following analysis was obtained:

MESH	SIEVE OPENING	AMOUNT PASSING
	mm.	%
20	0.833	100.0
24	0.701	95.85
28	0.589	79.15
32	0.459	23.55
35	0.417	1.85
42	0.351	0.0

From a plot of the sieve analysis curve, it was found that the effective size was 0.46 mm. and the uniformity coefficient was 1.22.

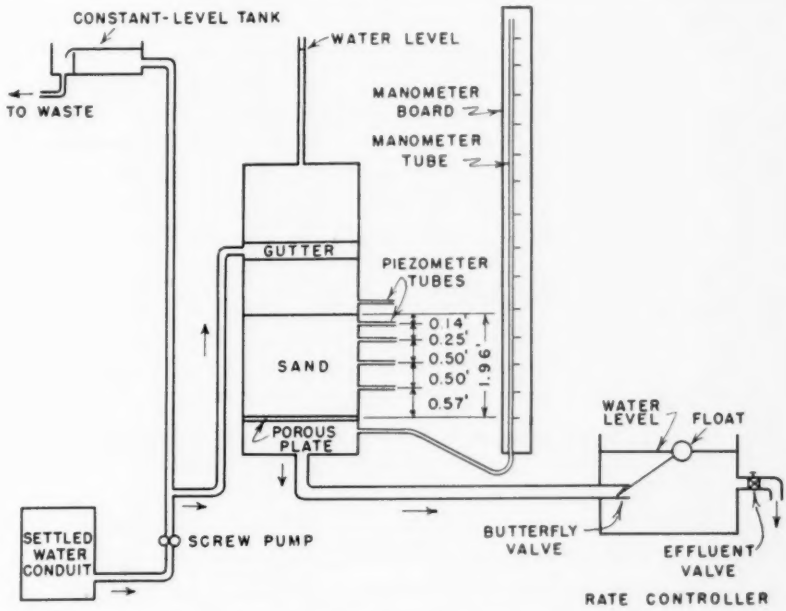

FIG. 2. Layout of Providence Experimental Filter and Auxiliary Equipment

Most of the finer material had been sieved out in order to obtain a sand which was fairly uniform and of a size large enough to prevent the accumulation of much floc on the surface of the filter. The specific gravity of the sand was 2.65. The average porosity of the filter layer after each wash was 40.8 per cent. Care was taken to permit the sand to settle to a fixed depth in order to maintain the same initial porosity for each run.

Characteristics of Floc

The size of floc particles and their concentration in the water are very important in determining the length of filter runs. Baylis (2) has emphasized this in saying, "The first step in the development of a theoretical equation for computing a predicted filter performance must be a means of computing the clogging tendency of the suspended matter in the water." The characteristics of floc are considerably different at separate plants, and vary over a considerable range at each plant. The dissolved, colloidal and suspended matter in the water, the chemicals added, the hydrogen ion concentration (pH) of the water, coagulation facilities, temperature, and length of settling period all have their influence on floc characteristics.

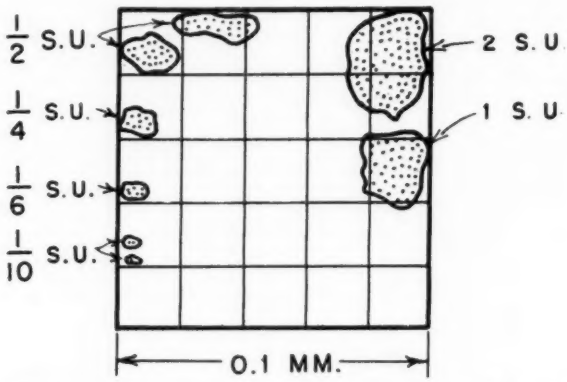

FIG. 3. Enlargement of 0.1-mm. Square; showing relative size of floc particles (Area of one division, 0.02 sq.mm., equals 1 S.U.)

At the filtration plant of the City of Providence, the raw water total solids content was about 50 p.p.m. Ferric sulfate was added as the coagulant and lime was added to bring the pH up to 10.0 (3). The settling period was exceptionally long, from 48 to 96 hr. Most of the floc settled out in these basins; and, as a result, the floc particles going to the filter were very small. Determinations of the size of floc particles were made by means of microscopic examination. Carbol fuchsin was added to the water to make the translucent particles more visible. An ocular micrometer and a microscope were used to measure the area of the floc particles. The smallest divisions of the micrometer were .02 mm. or 20 microns on the side. The area of one of these squares is 0.0004 sq.mm. or 400 sq.microns, and

is known as one standard unit (S.U.). The particles were small enough to consider the standard unit as the unit of area.

Figure 3 shows the larger 0.1-mm. square subdivided into 25 S.U. squares. Floc particles are shown in these squares to give an idea of their shape and size as seen under the microscope. The dots represent black granules and the shaded portions the jelly-like substance of which the floc is composed. The magnification is approximately 500.

A method similar to that used in the examination of water for microscopic organisms was applied in determining the areas of the floc particles. A portion of a sample of water was taken in a pipette and placed in a counting cell. The cell was placed under the microscope, and a number of fields of view, 1 mm. square, were examined. For ease of computation, certain fractions of standard units were chosen and the value selected nearest the observed area. In each field the number of particles of each area was counted, giving a tabulation of the sizes of floc and their relative numbers. The arithmetical average of the areas was chosen as the index of the size of the floc particles. It is not known what measure of this size it is possible to include in a rational theory of filtration. Subsequent research will have to be carried out to find the proper index of the size. It must be realized that the particles of floc visible under the 100-power microscope were not the only ones present in the water. They actually ranged from the largest ones noted down to colloidal dimensions. These latter particles also take part in clogging the filter, but not to such a great extent as the larger.

The determination of the concentration of flocculated matter in the water is an important factor. A floc particle consists of hydrous ferric oxide, the solid matter removed from the water, and considerable adsorbed water. The criterion of concentration should be the total volume occupied by floc per unit volume of water. It was not possible to obtain this value with any degree of accuracy for the low concentrations met with in these experiments. As an alternative, an index of the concentration of the flocculated matter in the water had to be sought. The suspended solids test gives the dry weight of suspended solids per unit weight of water, usually expressed in parts per million. For water in which the concentration of suspended solids is relatively high, this might give good results, but the suspended solids in the settled water at Providence was only 7.3 p.p.m.; and after having passed through the filter, it was almost zero. The

results of this test depend on the difference between two small quantities, in both of which there are chances for error; therefore, accuracy should not be expected.

Some experimenters use the turbidity of the water as an index of the concentration of flocculated matter. In the experiments described herein, turbidity readings of the samples were taken for several runs, but no consistent results were obtained. One of the reasons for this is that the turbidity of the settled water was usually less than 1 p.p.m. With the Hellige turbidimeter used, it was not possible to get readings closer than 0.05 p.p.m.; and for the work involved, greater accuracy was necessary.

The test for the iron content of the water is relatively simple. It gave an accuracy within 0.01 or 0.02 p.p.m. for the concentrations of iron encountered in these experiments, i.e., between 0.04 and 0.60 p.p.m. The iron content of a given volume of water may conceivably be a good index of the average concentration of the floc particles. Although the ratio of iron to volume may vary with discrete particles, the average of great numbers should be relatively constant. In the settled water at Providence, the number of particles visible under the 100-power microscope ranged between 10,000 and 20,000 per ml. Some tests were made to determine the ratio of iron to suspended solids in the water applied to the filter. Several tests showed this ratio to be about 8.5 per cent, with variations of only 0.1 per cent, although the iron content varied from 0.21 to 0.62 p.p.m. Furthermore, the results obtained in the tests, using iron as an index, showed no marked inconsistencies or contradictions. These findings further validate the use of iron content of the water as an index of the concentration of flocculated matter.

Experimental Procedure

After a thorough washing of the filter, the influent and effluent valves were opened and filtration started by adjusting the rate controller. Equilibrium conditions were reached in a relatively short time and filtration was maintained at a rate of 2 g.p.m. per sq.ft., giving a total of 4.04 g.p.m. for the entire filter. Readings of pressure were taken at frequent intervals by means of manometer tubes connected to the piezometers at various depths in the filter, as shown in Fig. 2.

Approximately every 12 hr. or from 8 to 12 times during a run, samples of water were taken through each of the piezometer tubes.

The inlet to each tube was located in the center of the filter. A 3-foot length of rubber tubing was attached to the piezometer. At the discharge end of this tubing were a short hypodermic needle acting as a nozzle and a pinchcock acting as a valve, to regulate the flow. For 5 min. the water was allowed to flow through the sampling tube at a rate of about 250 ml. per min. This was necessary to allow the coating on the sand grains in the immediate vicinity of the piezometer tube to wash off and float away before taking the actual sample. After 5 min., the rate was cut down to about 100 ml. per min. and allowed to flow for ½ min. longer to be sure that all excess floc was washed out. Then a sample of between 250 and 500 ml. was selected. This procedure was followed for each sample taken throughout the depth of the layer. Since the total rate of filtration was 4.04 g.p.m., or 7,646 ml. per min., sampling at the rate of 100 ml. per min. did not disturb the remainder of the filter layer. Each sample was then tested for its iron content. Microscopic analyses were made two or three times during each run to determine the average size of floc particles in the samples.

The filter was operated until the total head loss reached a value between 6 and 8 ft., giving a length of run between 70 and 140 hr. The sand layer was then washed, the wash water valve being set at a rate which gave an expansion 60 per cent of the filter layer. This rate was continued until the sand looked clean, and then the valve was closed slowly to permit the sand to settle to the same depth after each wash and thus obtain the same average porosity at the beginning of each run.

Results of Experiments

A considerable number of runs was made, all giving somewhat similar data. For the purpose of comparison, the results of two representative runs will be reported here.

The average size of floc particles at different depths for the two runs are presented in Table 1. Areas were all measured in standard units (1 S.U. equals 0.0004 sq.mm.). "Trace" signifies that a few small particles were visible, perhaps one or two in ten fields of 1 sq.mm. each. The hours represent the time at which the sample was taken, time being measured from the beginning of the run.

The results obtained during runs have been plotted on four different types of graphs. One series (Fig. 4) shows the relationship of loss of head to time at various depths in the filter. The observed values of

lost head have been adjusted to the temperature of 4°C., taking into account the change of viscosity with temperature. The actual temperatures did not vary more than one degree from that value, so only slight adjustments were necessary.

Another series of curves (Fig. 5) shows the relationship of the iron content of the water to the depth in the filter at frequent intervals during the run; and a third series (Fig. 6) is a combination of the two previous sets, in which the removal of iron in four successive layers of the filter in the plots of iron removal against time, and of lost head against time, are also shown for each of these layers. The data for Run 2 are presented in Fig. 7, where somewhat different conditions prevailed.

TABLE 1

Average Size of Floc Particles at Different Depths of Filter Layer for Two Representative Runs

DEPTH OF FILTER LAYER IN FEET	AVERAGE AREAS OF FLOC PARTICLES IN STANDARD UNITS			
	Run 1		Run 2	
	47 Hr.	95 Hr.	22 Hr.	118 Hr.
Influent	0.278	0.230	0.137	0.133
0.14	0.166	0.163	0.125	0.126
0.39	0.149	0.140	Trace	0.122
0.89	0.100	0.100	None	0.113
1.39	Trace	Trace	None	Trace
Effluent	Trace	Trace	None	Trace

For Run 1, curves (Fig. 8) showing the rate of iron removal in parts per million per inch of depth have been plotted for every 20 hr. during the run. These values were obtained by dividing the iron removal in each layer (Fig. 6) by the depth of the layer, giving the average removal per inch of depth. Being the average, the values are plotted at the center of the respective sections of the layer.

Significance of Results

The most significant results of this research are those which show the time rate of removal of solid matter from the water in different layers of the filter, and the variation of this removal during the length of the run. These are shown on Fig. 6 for Run 1 and Fig. 7 for Run 2. In Table 1, it will be noted that the average areas of the floc particles

in the water being filtered during Run 1 were twice those prevailing in Run 2, and that the iron content of the water was 0.50 p.p.m. during Run 1 and 0.35 p.p.m. during Run 2. Different results were obtained in each case.

In the layer comprising the first 0.14 ft. of depth in the filter, the iron removal, and with it the removal of the colloidal and suspended

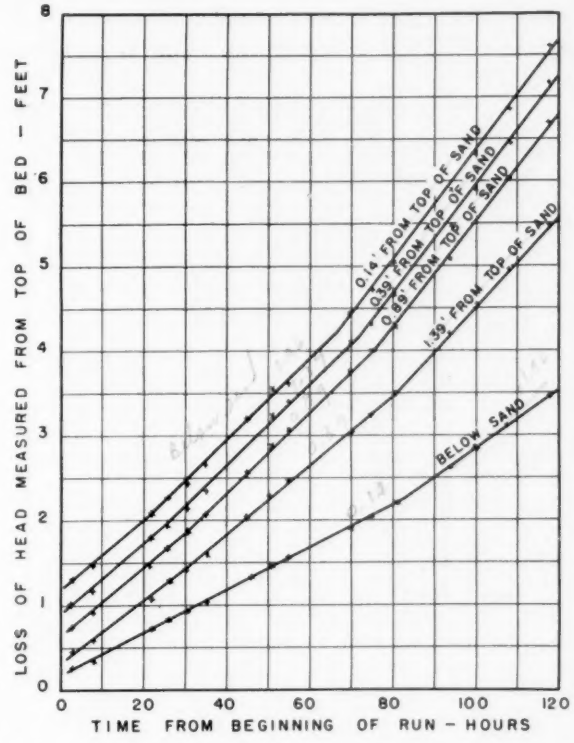

FIG. 4. Relationship of Lost Head to Time at Various Depths in the Filter—Run 1

solids comprising the floc particles, began at its maximum value and continually decreased until a saturation point was apparently reached. This made it appear that no more floc could be deposited. The lost head, however, continued to build up at a practically constant rate, regardless of this saturation, a fact which would tend to indicate that flocculated matter was still being removed from the water in passing through this layer. Of course, consolidation of the bed might have

caused some increase in lost head, but this alone would not keep the time rate of increase of lost head so nearly constant. It is probable that the test for the iron content of the water was not sensitive enough to indicate the very slight amount of iron which may have been removed in this top layer.

The second layer was 0.25 ft. in depth, extending from 0.14 to 0.39 ft. below the top of the sand. The removal in this layer began at a fairly high value and increased as the removal in the top layer decreased. A period of maximum removal was reached and

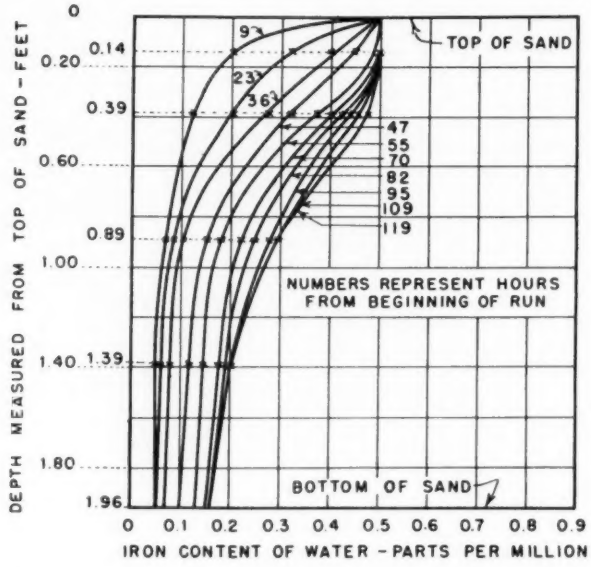

FIG. 5. Relationship of Iron Content to Depth in Filter at Various Times During the Run—Run 1

then decreased gradually until the layer was nearly saturated with flocculated matter. The lost head variation with time was observed to be nearly constant, a condition similar to that which prevailed in the layer above.

Removal in the third layer began at a low value, since the two layers above were removing most of the flocculated matter at the beginning of the run. As the removal in the top layer decreased rapidly, and the removal in the second layer reached its maximum and began to decrease, more material passed through to the third layer. The removal increased steadily and near the end of the run it carried

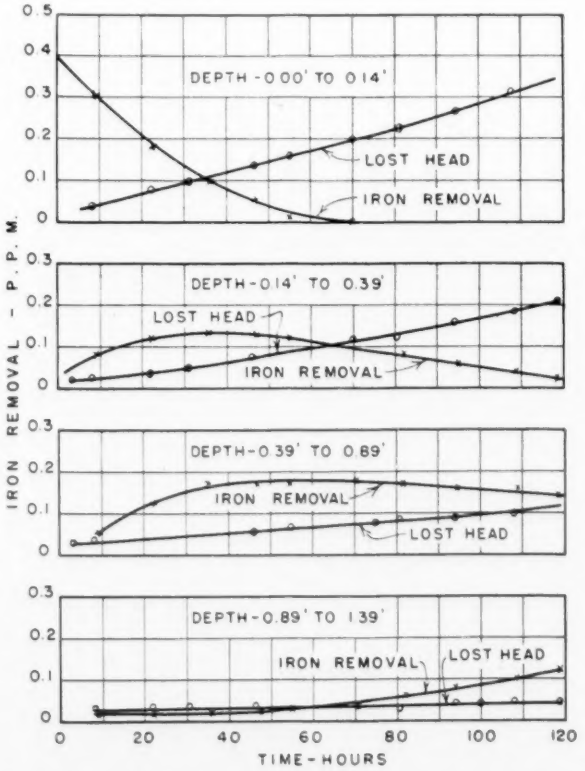

FIG. 6. Relationship of Iron Removal and Lost Head to Time for Various Layers of the Filter—Run 1

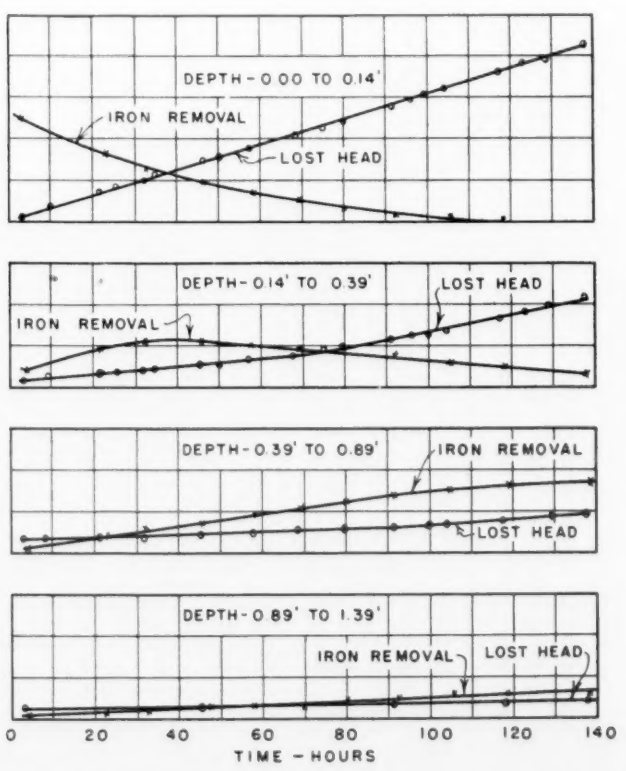

FIG. 7. Relationship of Iron Removal and Lost Head to Time for Various Layers of the Filter—Run 2

most of the burden of filtration. In the first run, the removal in this layer reached its maximum value and began to decrease after 70 hr. In the second run, the smaller floc particles and the lower concentration of removable matter did not permit the removal in this layer to reach its maximum value, although the curve had begun to flatten out near the end of the run.

The fourth layer in the filter was 0.50 ft. deep and extended from 0.89 to 1.39 ft. below the surface. During the first part of the run, very little iron was removed. As the two top layers decreased their removal, the third layer could not remove all of the flocculated matter which came to it, and more passed through to the fourth layer and

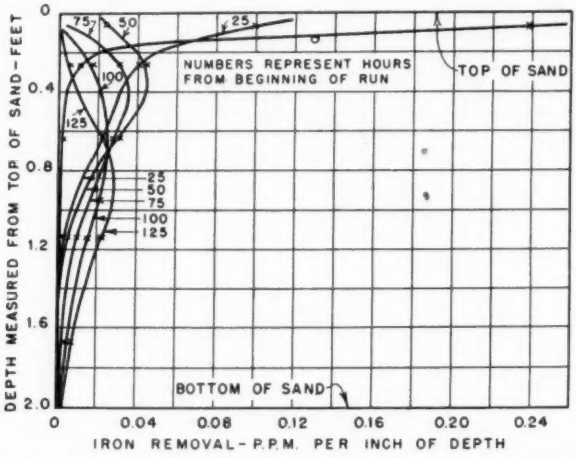

FIG. 8. Relationship of Iron Removal per Inch of Depth to Depth at Various Times During the Run—Run 1

near the end of the run it removed an appreciable amount of iron from the water.

The bottom layer of the filter was 0.57 ft. deep, extending from 1.39 ft. to the bottom of the sand bed, 1.96 ft. from the surface. The iron removal and increase of lost head, during the run, in this layer were practically negligible.

For the first run, curves have been plotted (Fig. 8) to show the relationship of the iron removal per unit depth to the depth in the filter for various times during the run. These curves show that the removal is a maximum in the top portion of the unit for a considerable part of the run. As the upper pores become clogged, the section of maximum removal moves downward in the filter.

The depth to which floc penetrates in the filter has long been the subject of discussion. The curve of iron content against depth (Fig. 5) shows that some iron was in the effluent at all times during the run. Ferric hydroxide, or hydrous ferric oxide, is known to be practically insoluble. At the beginning of the run, 0.05 p.p.m. of iron was in the water. Even if this were the upper limit of solubility, the increasing values of iron content in the filter effluent would indi-

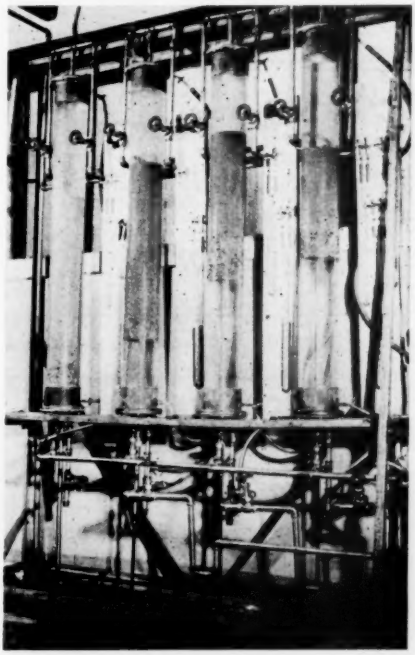

FIG. 9. Experimental Filters at the Sanitary Engineering Research Laboratory at New York University

cate that some floc must have been penetrating the layer. At the end of the run, the iron content measured 0.16 p.p.m. The fact that floc penetrated the whole depth of the layer was further proved by the discoloration of the sand grains by adsorbed ferric oxide on their surfaces. These observations relate only to the sand and the characteristics of the flocculated matter in use during the course of these experiments. Armstrong (4) observed a similar phenomenon when dealing with coarse grained sand.

The straight-line variation of loss of head with time has been pointed out by previous investigators (4, 5, 6) in this field. Only a slight deviation from this condition was observed in the experiments discussed here. The sudden increase in rate after 80 hr. in Run 1 and 85 hr. in Run 2 can, perhaps, best be explained by consolidation of the layer and the rearrangement of the sand grains taking place under the increased pressure of the higher lost heads. It was thought that the unusual length of these runs might involve a time factor which would encourage consolidation.

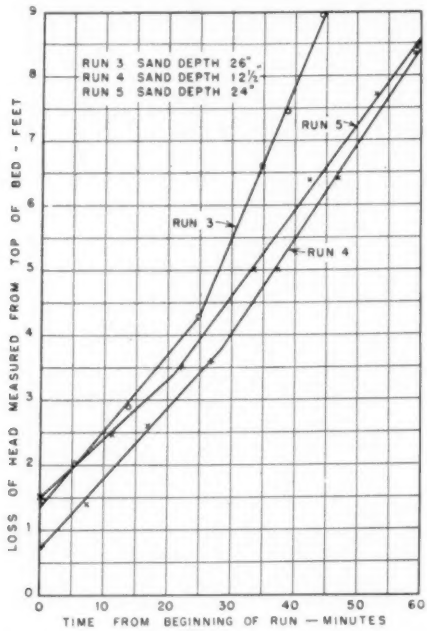

FIG. 10. Relationship of Lost Head to Time for Short Runs

Further runs were made on the experimental filters (Fig. 9) in the Sanitary Engineering Research Laboratory at New York University (7) under entirely different conditions. Results, however, were similar to those noted above. The filters were filled with sand of local origin having an effective size of 0.228 mm. and a uniformity coefficient of 2.83. The depths of the filter layers were as noted in Fig. 10. In order to obtain short runs, the influent to the filters was dosed with 70 p.p.m. soda ash and 170 p.p.m. alum and mixed for a

short time to give a turbidity of 57 p.p.m. and considerable flocculated matter. The results of three runs on these filters are also shown in Fig. 10. A lost head of 8 ft. was reached in less than an hour in all cases. A sudden increase in the rate of variation and lost head was observed in each of the runs. As noted in the previous experiments, with longer runs, the lost head assumed a straight-line variation on both sides of the change in rate. The marked difference in the length of the runs in the two series of experiments would tend to eliminate the consideration of a time factor in the apparent consolidation or other change taking place in the sand. The high pressure differential between various depths was present in both cases and would be the governing factor in causing changes in the condition of the filter.

Conclusions

As a result of this experimental work, the following conclusions may be drawn:

1. The entire filter unit shares the burden of removal of flocculated matter from the water. The upper portion performs most of the removal at the beginning of the run, but as the upper pores become clogged, the burden is taken successively by the lower portions of the filter.

2. The removal of solid matter from the water in the upper two inches of the filter gradually becomes very small, approaching zero toward the end of the run.

3. The small amount of removal taking place during the latter part of the run in the upper two inches of the filter is enough to continue the straight-line variation of increase of lost head with time.

4. Throughout the length of each run, the lost head is directly proportional to time.

5. Deviations from this straight-line variation may occur irrespective of the length of time necessary to complete the run.

The author wishes to express his appreciation for the counsel of Thomas R. Camp, Associate Professor of Sanitary Engineering, Massachusetts Institute of Technology; and to Elwood L. Bean, formerly chemist of the Providence Filtration Plant, and at present Sanitary Chemist of the City of Philadelphia. The co-operation of the Department of Public Works of Providence, R. I., was also of great assistance in the conduct of this research.

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Measuring Low Sulfide Concentrations

By Richard Pomeroy

IN DEALING with problems of removing sulfides from water supplies or of preventing their formation in water mains, it is desirable to have information regarding the prevailing concentrations. Such determination often requires analysis of very low sulfide concentrations, for a few hundredths of a part per million of sulfide will cause an objectionable odor and taste in water.

When measuring sulfide concentrations above 1 p.p.m., the usual iodine titration method is fairly satisfactory, although the results are generally somewhat high due to the presence of thiosulfate and other reducing substances (1). At concentrations below 1 p.p.m., however, this method becomes increasingly unreliable. Its accuracy and range can be extended by making use of the modified procedure in which the sulfides are evolved in a gas stream and carried to a zinc acetate receiving solution before titration; but even this procedure cannot be used for concentrations below 0.1 p.p.m., except by the use of samples of several liters. Thus, the iodine method is of little use for the determination of concentrations in the neighborhood of the threshold of odor and taste.

The author has been successful in making such determinations by a modification of the methylene blue method which is now extensively used for determining sulfides in sewage (2).

Application

1. The method is recommended for sulfide concentrations from 0.005 p.p.m. to 5 p.p.m., but may be extended to higher concentrations by slight modification. As far as is known, it is not subject to interference by any substances found in water supplies, except for the possible presence of hyposulfite (1) which decomposes to yield hydrogen sulfide when the sample is acidified.

A contribution by Richard Pomeroy, Montgomery & Pomeroy, Engineers-Chemists, Pasadena, Calif.

Solutions Required

2. (*a*) *Stock amine-sulfuric acid solution.* Distill para-amino-dimethyl-aniline in an all-glass apparatus from which the air has been displaced with inert gas. Mix 50 ml. of concentrated H_2SO_4 with 30 ml. of water and cool. Add to this 20 grams of the purified amine, stirring until solution is complete. Make up to 100 ml. with water. This stock solution will discolor somewhat on standing, but its usefulness remains unimpaired.

(*b*) *Amine-sulfuric acid test solution.* Dilute 10 ml. of the stock amine-sulfuric acid solution with 990 ml. of 1:1 sulfuric acid.

(*c*) *Ferric chloride solution.* Dissolve 100 grams of $FeCl_3 \cdot 6\ H_2O$ in enough water to make 100 ml. of solution.

(*d*) *Ammonium phosphate solution.* Dissolve 400 grams of di-ammonium phosphate in enough water (805 ml.) to make 1 liter of solution.

(*e*) *Methylene blue solution.* Dissolve 520 mg. of methylene blue in 1,000 ml. of water.

(*f*) *Low-strength methylene blue solution.* Dilute a portion of the above methylene blue solution to one tenth strength.

(*g*) *Comparison water.* If the water being tested is free from any detectable color or turbidity, standards for comparison may be made with distilled water; otherwise it is preferable to prepare water for comparison by removing the sulfides from a sample of the water being tested. This may be done by aerating the water and storing it for a few hours to assure oxidation of the sulfides; by making a sample slightly acid and aerating it for a half hour; or by adding a slight excess of chlorine and then dechlorinating with thiosulfate.

Procedure

3. *Preparation of sample.* Mark two Nessler tubes at 40 ml. Run the water to be tested through one of these by means of a rubber tube extending to the bottom, so as to flush the tube and leave it filled with water which has had no contact with air. Remove the rubber tube and siphon or pipette off the excess water down to the 40-ml. mark. Fill the other Nessler tube to the 40-ml. mark with the water to be used for comparison.

4. *Color development.* To each tube add 2.5 ml. of the amine-sulfuric acid test solution, followed by 0.5 ml. of the ferric chloride

solution. Close the tubes with the thumbs and mix by inverting slowly once or twice. Allow these tubes to stand for ten minutes; then to each add 9 ml. of the ammonium phosphate solution and again mix. Allow to stand for an additional five minutes before judging the colors. The presence of sulfides is shown by a blue color.

5. *Measurement of the color.* By means of droppers which deliver 20 drops per ml. add the methylene blue solutions dropwise to the second tube to match the color in the first tube. (In measuring by drops, hold the droppers steadily in a strictly vertical position. The tips must be kept clean so that the drops cling uniformly to the periphery of the outlet.) For low concentrations the comparisons may be made by viewing longitudinally against a white background. For higher concentrations they may be viewed transversely, but in this case it is necessary to add water to the unknown tube to keep the volume equal to that in the tube to which the dye is being added. If the methylene blue is of proper strength, one drop of the solution with 520 mg. per liter is equivalent to 0.1 p.p.m. and one drop of the 52 mg. per liter solution is equivalent to 0.01 p.p.m.

Standardization

6. Since samples of methylene blue dye may vary in tinctorial strength, the method should be standardized against sulfide solutions of known strength, as follows:

(*a*) Completely fill a one-gallon bottle with acidified water. Add a washed crystal of sodium sulfide amounting to about 50–75 mg. Stopper and mix thoroughly. Siphon a sample from the bottom of the bottle into a Nessler tube and proceed with the colorimetric test.

(*b*) Pipette 10 ml. of $N/40$ iodine solution into a clean, dry 500-ml. volumetric flask. Siphon in sulfide solution up to the mark, transfer to a suitable beaker, add 1 ml. of conc. H_2SO_4 and titrate the excess iodine with $N/40$ thiosulfate, using starch solution as indicator. Multiply the net volume of iodine used by 0.818 to ascertain the concentration of sulfide in p.p.m. Adjust the methylene blue solutions so that they give the same result as the iodine titration.

Variations

7. If it is desired to apply the method to samples having up to 20 p.p.m., but not lower than 0.2 p.p.m., of sulfides, prepare the amine-

sulfuric acid test solution by using 25 ml. of the stock solution instead of 10 ml. per liter. For concentrations above 0.5 p.p.m. interfering colors due to the reagents are negligible and the comparative tube may be prepared by using the same water as is being tested, but using 1:1 sulfuric acid instead of the amine-sulfuric acid test solution. Volumes of sample and reagents may be reduced proportionally, in which case the procedure becomes the same as for testing sewage (2).

Accuracy

8. On the basis of experience, and previously published research on the methylene blue method, it is estimated that the probable error of the results, in the hands of the average operator, will be 10 per cent for sulfide concentrations above 0.1 p.p.m., and 0.01 p.p.m. for lower concentrations, except that the method reliably detects as little as 0.005 p.p.m.

Forms of Sulfides

9. *Forms measured in the test.* Both the iodine method and the colorimetric method measure total sulfides, which include hydrogen sulfide, H_2S, and hydrosulfide ion, HS^-. (Any acid-soluble metallic sulfide present as suspended matter is also included. If desired, such metallic sulfides may be removed by settling, using a little alum and sodium hydroxide to aid settling when necessary.)

10. *Significance of hydrogen sulfide.* When treating water supplies to remove sulfides, the total dissolved sulfide content must be taken into account, since hydrogen sulfide is present as long as any dissolved sulfide is present. The intensity of odor and taste, however, is determined by the concentration of hydrogen sulfide.

11. *Calculation of hydrogen sulfide.* Hydrogen sulfide may be determined by multiplying the dissolved sulfide concentration by a factor dependent upon the pH. This factor may be calculated by the formula:

$$\log\left(\frac{1-f}{f}\right) = \text{pH} - \log K'$$

in which f is the factor and K' is the apparent ionization constant of H_2S. The best value of this constant for a typical water supply and a temperature of 20°C. is 1.6×10^{-7} ($\log K' = -6.8$) (3). Values of the factor for certain pH values are as follows:

pH	*Factor*
5.0	0.98
6.0	0.86
6.5	0.67
7.0	0.39
7.5	0.17
8.0	0.060
9.0	0.0063

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Development of Public Water Supplies in West Virginia

By H. K. Gidley

THE earliest water supplies developed in West Virginia were the natural springs which abound along the eastern border of the state, from Morgan County on the north to Monroe County on the south. At an early date many of these springs were nationally famous and widely patronized; in that sense they may be considered public supplies. For example, George Washington visited the warm springs at Berkeley Springs on March 18, 1749. These springs had a reputation even then, for in his diary he speaks of them as the "famed warm springs." Incidentally the springs today serve, as the source of water supply for the City of Berkeley Springs. Other famous springs developed in the late Eighteenth or early Nineteenth Centuries include Old Sweet, White Sulphur and Capon.

Water was first distributed in the towns by water carts. According to the early records in Wheeling, a water cart was a 120-gallon barrel mounted on two wheels and an axle. These horse-drawn carts were backed hub deep into the Ohio River and filled by means of a dipper on a long pole. The governing body of the city fixed the price at two barrels for a quarter.

Wheeling was the first city in the state to have a public water supply distributed under pressure; and this was one of the first systems west of the Alleghenies. An act of January 3, 1829, authorized the Mayor and Commonalty to raise $30,000 by lottery to erect the water works necessary to convey water from the Ohio River to the borough. While no record of a lottery or the amount raised is available, it is probable that such a water works lottery was held, since, in those days, it was a common means of raising money.

A paper presented on October 26, 1940, at the West Virginia Section Meeting, Huntington, W. Va., by H. K. Gidley, Associate Engineer, State Health Department, Charleston, W. Va.

The first Wheeling system was completed and the pump started on August 16, 1834. According to the Wheeling Directory for the year of 1839, the steam engine operating the pump had a 20-inch cylinder and an 8-foot stroke. The four boilers were each 30 in. in diameter and 20 ft. long. The pump had a 12-inch cylinder and an 8-foot stroke and delivered 94 gal. with each revolution of the wheel. Since the wheel revolved eleven times per minute, the pumping rate was 1,034 g.p.m. The iron pipe leading from the pump to a 500,000-gallon reservoir was 14 in. in diameter and 1,000 ft. long and the static pumping head was 172 ft. The plant operated 12 hr. per day except on the Sabbath, and delivered 744,000 gal. The steam engine consumed 120 bu. of coal each day at $3\frac{1}{2}$ cents per bu., and the system returned a profit of $1,500 to $2,000 per year. By 1839, this original plant was inadequate and plans had been formed for a larger installation.

Wheeling continued using untreated water from the Ohio River until 1918, when chlorine was first applied. The modern filtration plant now in use was placed in operation in 1925.

The next public water system of which the author has a record was installed in Martinsburg in 1872. The source of supply for this system was two limestone springs located east of the city near Tuscarora Creek. Pumping equipment consisted of one hydro-steam rotary pump and four reciprocating pumps. Power was obtained from water wheels on Tuscarora Creek supplemented by steam. A pressure of 40 lb. was maintained in the system by direct pumping, except during a fire when it was increased to 80 lb.

The original Martinsburg distribution system was constructed of cement-lined riveted wrought-iron pipe. This system was abandoned in 1903 and replaced with cast-iron pipe. The present source of water supply, consisting of limestone springs having a capacity varying between 1.65 and 4.00 m.g.d. was also placed in service in 1903. This supply has been chlorinated since 1912.

Major Development of Supplies

A major development in public water supply in West Virginia occurred between 1880 and 1900. Records are not complete, but the following cities report the installation of water systems during this period or immediately thereafter: Bluefield, 1890; Buckhannon, 1901; Charleston, 1886; Chester, 1899; Clarksburg, 1888; Elkins, 1900; Fairmont, 1903; Grafton, 1896; Huntington, 1886; Mounds-

ville, 1892; Morgantown, 1888; Parkersburg, 1884; Sistersville, prior to 1897; Weston, 1896; Wellsburg, 1882; and Williamson, 1904. In about 1900, the cities began to be concerned about the quality of the water in their distribution systems. Typhoid due to polluted water supplies was exacting a heavy toll.

Filtration Plants

Apparently Huntington was the first city to employ rapid sand filtration, as circular filters were added to its system in 1898. This city also reports using coagulation in 1900. Two Jewel-Continental tub filters were installed in Morgantown in 1900 and are still giving good service. In 1906 Charleston installed six 1-mil.gal. rectangular concrete filters which are still in service, and at the same time initiated coagulation as part of its treatment. Finally, in 1911, the Clarksburg plant was built.

Slow sand filters have never been used to any extent in West Virginia, although several communities have attempted to take advantage of natural filtering material deposited in the river beds. The most successful of these, at Chester, is still in operation after 41 yr. of continuous use. The infiltration crib at Chester was constructed in 1899. Sand and gravel in the river bed were removed to a depth of 12 ft., and in the excavation was placed a crib, 20 ft. by 80 ft. by 6 ft. deep, constructed of a criss-cross of timber. The crib was backfilled with sand and gravel to the normal level of the river bottom. The underdrain of the crib was then piped to a wet well from which the water was pumped into the system. The water reaching the wet well is apparently from an underground source and this accounts for the success of the installation. Newell installed a system similar to that at Chester, but this has been superseded by a well, although the old crib is retained in working condition.

Parkersburg System

Parkersburg has had a varied experience with its water supply. The original system was installed in 1884, pumping untreated water from the Ohio River. In 1908, a consulting engineer was employed to advise the city on a source of water supply, and he recommended a series of wells in the gravel deposit along the river. After some local controversy two other consultants were engaged to check the first study. They confirmed the report that a well supply could be developed, but advised that a filtration plant, using the Ohio River

as a source of supply, offered certain advantages over a long period. The city voted bonds to construct the filtration plant, but, before the project could get under way, a controversy again developed and a scheme devised by a fourth engineer was adopted. This system was installed in 1911–12 at a cost of $284,000. It involved the excavation of an area 110 ft. wide by 656 ft. long to a depth of 5½ ft. in a sand

TABLE 1

*Data on West Virginia Public Water Supplies**

Total number of communities served by public water supplies	461
Total number of supplies listed	431
Total population served by public water supplies	848,300
Total population of State (1930)	1,729,205

TYPE OF SUPPLY	NUMBER	POPULATION
Underground water	330	421,786†
Drilled wells	232	272,937
Dug wells	6	8,976
Springs	37	65,157
Mine water	55	74,716
Surface water	132	550,916†
TREATMENT OF WATER		
Coagulation	95	525,971
Sedimentation	121	618,399
Filtration (pressure)	41	45,810
Filtration (gravity)	96	559,918
Chlorination	187	693,887
OWNERSHIP OF SUPPLIES		
Public	90	315,569
Private	341	532,731

* This list of public water supplies includes the numerous large and small mining towns which have central systems that distribute water under pressure.

† The sum of these figures exceeds the total population served, since many supplies use more than one source of water.

bar in the Ohio River. An underdrain system of manifolds and laterals was placed on a 6-inch gravel layer and covered with 12 in. of gravel. Above the gravel was placed 3½ ft. of clean washed Ohio River sand. This filter was divided into five units, and the underdrain system was arranged so that each unit could be backwashed from a wash water tank. The filter functioned very well for a few

years, but, by 1916, the river began to break through craters which developed in the sand unit. By 1920 it was apparent that a new supply would have to be developed. In 1928, then, the city again turned to the first consulting engineer and the well supply he had recommended 20 yr. before was installed. In 1939, a rapid sand filtration and zeolite softening plant was placed in operation to improve the quality of the well water. The old filter system is still in place and is kept for emergency use.

Chlorine was first applied in the form of chloride of lime in 1911 at Clarksburg. Martinsburg and Williamson shortly thereafter employed hypochlorite. According to a 1917 report in the State Health Department files, liquid chlorine was applied first at Bluefield on July 2, 1914.

Summary

Public water supply has come a long way since John Moore, authorized steamboat inspector for the Port of Wheeling, opened the throttle of the steam engine at the new water works on August 16, 1834. The 1940 list of public water supplies in West Virginia published by the State Health Department records 431 systems supplying 461 communities. Table 1 indicates the source, treatment and population served by these supplies.

The largest filter plant equipped for operation (capacity, 20 m.g.d.) is at Wheeling. A wartime plant at Nitro was built to treat 40 m.g.d. but less than half of that capacity is available for use at present.

Parkersburg is the largest city which depends upon wells for a supply, and Martinsburg is the largest community supplied by spring water.

Creston, Iowa, Solves Its Water Problem

By Arthur K. Olsen

DURING the severe drought of 1934, the water supply of Creston, Iowa, failed completely. Water had to be shipped in tank cars from Council Bluffs, a distance of 100 miles, for a period of six months. For those six months there was hardly enough water available for drinking and cooking purposes, and bathing was severely curtailed unless one was fortunate enough to have an old well in the back yard. Anyone who has found it necessary to get along on five gallons of water a day in a modern house will have some idea of the situation. If ever the citizens of a community came to realize what a water system really means, it was in Creston in 1934.

But how did such a catastrophe occur? Whose fault was it? As is usual, when a crisis such as this occurs, the blame had to be placed on someone. The public itself never seems to realize that many times it is its own lack of interest and understanding which must bear a portion of the blame. In this instance, the privately owned water company was charged with the entire responsibility, and feeling against the organization was strong. At the time, the author was not connected with the water company, but was living in Creston, so his observations until the date that ownership changed hands are made from a neutral standpoint.

The old company, while far from blameless, could not be charged with the entire responsibility for the fiasco. True, the trouble was caused by insufficient storage, and a warning of possible impending shortage given in 1930 had been ignored when plentiful fall rains and snows again filled the reservoir—once the reservoir was full again, all fears quickly subsided and the warning became a memory. Then too, the company's public relations were in a deplorable state, so

A paper presented on November 14, 1940, at the Missouri Valley Section Meeting, Omaha, Neb., by Arthur K. Olsen, General Manager and Engineer, Creston City Water Works, Creston, Iowa.

much so that when an attempt was made to acquaint the citizens with the seriousness of the situation, the response was not what it should have been.

These, of course, were responsibilities of the company and properly chargeable to them. On the other hand, the company had been operating for a number of years without a franchise, which it had repeatedly requested but failed to obtain. Without it, the company could hardly be expected to undertake the extensive improvements needed; and so the matter drifted along. Under the circumstances, therefore, it would seem that the citizens should bear some of the blame, because, since they did not wish to grant a franchise, so that the private concern could operate properly, they should have taken steps to acquire the property thus permitting necessary improvements.

This situation serves to illustrate how easy it is for an emergency such as this to occur, unless the public can be aroused to its danger. It also illustrates the value of good public relations built on confidence—confidence of the community in their water works officials. This the old company did not have, so when it tried to point out the danger, the average citizen interpreted the warning as merely another excuse to get something for itself. Conditions such as this might produce a similar catastrophe in any community. When things are running smoothly, it is sometimes difficult to convince an apathetic public that a dangerous situation exists, especially if the expenditure of money is required to correct it. It is at this stage that good will and confidence are of immeasurable value and that a water works which has neglected these items may find itself in a difficult position.

Creston Water System

Creston obtains its water from a reservoir, which in 1934 covered 220 acres, and receives the runoff from 18 sq. mi. of gently rolling farm land. All streams flow only intermittently and a considerable portion of the water is received from tile drains which empty into them.

The reservoir, at the time, had a capacity of 400,000,000 gallons, having lost about 25 per cent of its capacity during the 40 years of its existence. This fact was determined by a survey made during the summer of 1934. The silting problem was, therefore, not serious and, in the years to come, the rate should be even less as soil conservation, utilizing contour farming, ditch checks, etc., becomes more prevalent.

The loss of the 25 per cent capacity, however, spelled disaster in 1934, for if it had been compensated for, no shortage would have occurred in spite of the unprecedented drought of that year.

A 2,000,000-g.p.d. steam pumping and filtration plant delivered the water to the city, a distance of 1½ mi. Distribution was through a system of 23 mi. of pipe, 75 per cent of which was cast iron.

As soon as it became apparent that a shortage was inevitable, a state of emergency was declared, limiting personal use to 5 g.p.d. per capita and industrial, to just sufficient to permit operations. Consumption, in this manner, was cut from 750,000 g.p.d. to 150,000 g.p.d. and arrangements were made to ship this amount of water daily in tank cars from Council Bluffs. Shipments began July 1, and continued until the middle of December, when a heavy rain, falling on the bare frozen watershed, filled the reservoir and ended the emergency.

Plans for Improvement

In this way the immediate problem was solved, if not adequately, at least after a fashion. Plans for a permanent solution then became the order of the day. Three different methods to accomplish this were possible:

1. The city could grant the private company a franchise in which the company would agree to make the necessary improvements.
2. The city could purchase the existing property, pay for it out of earnings, and operate it as a municipal utility.
3. The city could construct an entirely new plant and distribution system.

All of these methods were considered, but it was concerning the second and third that the battle finally raged. The first method had to be discarded because of the bitterness of the majority of the public toward the company. As mentioned before, there certainly were two sides to this question, but rightly or wrongly, the attitude was too prevalent for time to be wasted in overcoming it, and therefore the company franchise was given but scant consideration. The solution, then rested between purchasing the existing plant and building a new one.

To purchase the existing facilities it was necessary to agree upon a price, and this question led to heated controversy. The dissension over the purchase price caused the formation of a powerful group which did not want the old property at any price, advocating the

construction of an entirely new plant and distribution system. To find a site for the proposed reservoir, however, it would have been necessary to go 8 mi. east of the city, because no suitable sites, with the exception of the one belonging to the old company, 1½ mi. west, were available nearer than that. Aside from this difficulty, too, the entire old system was in good condition, and with improvements, costing but a fraction of a new plant, it was possible to make it a first class water system.

Nevertheless, the group was strong enough to convince a majority of the voters at the first election held that the old system should not be purchased. So, after several months of dispute, it seemed that the problem was no nearer solution than when the emergency began. A date for a second election was set, however, and a thorough campaign, in which all details were carefully explained to the voters, was conducted. In this second vote the issue was carried and the Council authorized to purchase the property and to provide for its administration by a board of trustees.

These events are mentioned in detail because they seem to illustrate so well what is likely to happen when emotion takes the place of reason. The construction of a new plant was sheer nonsense when the existing plant could be purchased at the price which had been agreed upon. A valuation survey had been made by a reputable firm of engineers and the estimate was considerably in excess of the $185,000 which the old company agreed to accept.

Under circumstances such as these it is almost impossible to obtain rational business-like consideration for a problem. Some of the misconceptions which arise are ridiculous. One in particular which the author remembers, because it became rather prevalent, was to the effect that the old reservoir was a *"burner."* Never having heard the term before, he inquired the meaning and was told that when lakes of the type of the reservoir once go dry, they never again will hold water—and this was actually believed by some supposedly intelligent people.

This has been a rather panoramic view of events which led up to the Creston City Water Works improvements. Such a large portion of the paper has been devoted to a discussion of these events because the problems involved were far more difficult than were those encountered in the improvements themselves.

On February 11, 1935, the plant became the property of the city under the management of a three-man board of trustees. Terms are for six years and staggered so that there is only one change every two

years. Active supervision of the plant is by an engineer-manager in charge of operations. It was under this reorganized set-up that the rehabilitation of the entire system was effected.

Provision for Additional Storage

The first problem, of course, was the creation of additional storage, the lack of which had precipitated all the difficulty. This was a relatively simple matter because the watershed of 18 sq. mi. was entirely adequate for a reservoir several times the size of the one in use. Accordingly, it was decided merely to raise the existing dam, which was an earth structure built across the narrow valley in 1895. The dam was of conventional design with an upstream slope of 2:1 and a back slope of 1½:1. Maximum height was 25 ft. with a uniform top width of 10 ft. Total length was 860 ft., and the spillway section near the center was 244 ft. long, 30 ft. wide and covered with a 12-inch concrete slab against vertical end walls, 5 ft. high.

The lake, Summit Lake, formed by this dam was 1½ mi. long and covered 220 acres of land, impounding about 400,000,000 gallons of water. The existing dam was in excellent condition, well compacted and entirely free from seepage, so it was entirely feasible to raise the crest by simply widening the base and carrying the fill up to the required elevation. This method of course, was the cheapest way to obtain the necessary additional storage.

It was decided to raise the spillway crest 3⅓ ft., the maximum allowable increase because of the grade elevation of a permanent highway bridge ¾ mi. north of the dam. This increase, however, doubled the capacity of the reservoir and provided storage for over a two year's supply. The earth portion was raised 5 ft. in order to provide 1⅔ ft. additional free board. A nearby deposit of clay was used because of its compaction qualities. The sod on the back slope of the existing dam was all carefully removed and horizontal trenches, 1 ft. wide and 2 ft. deep, were dug across the entire length at 3-foot intervals. In addition, the surface between these trenches was scarified to provide a lock and bond between the back slope of the dam and the new fill. All widening was done on the land side of the dam with the face projected up on the existing slope in order not to disturb the riprap.

The fill was started at the toe and carried up in 6-inch lifts which were thoroughly compacted by rolling. The entire face was then riprapped in the conventional manner.

The spillway crest was raised 3⅓ ft. by means of a concrete con-

ventionally shaped section with a 2:1 upstream slope and curved downstream face (Fig. 1). This small dam is $3_1^5{}_2$ ft. on the crest, $14\frac{3}{4}$ ft. at the base and contains 350 cu.yd. of concrete. Reinforcement consists of transverse bars with dowl bars into the concrete cut-off wall across the spillway mouth.

The only innovation in construction was the use of 100-pound rails 33 ft. long, driven through the spillway slab into the earth fill beneath and allowed to project 3 ft. above the slab. Two rows of such rails were driven, staggered at 5-foot centers across the entire mouth of the spillway, and the concrete poured over them. While it probably was not necessary to utilize such an involved method as this, it was, nevertheless, an inexpensive insurance against slippage between the new section and the spillway slab. The rails were purchased for 1

FIG. 1. New Spillway Crest Under Construction; showing projection of reinforcing rails

cent per pound and relief labor was used in placing them, so the cost was even lower than might be expected. Since the new construction was completed, the reservoir has several times frozen to a depth of 3 ft., with the surface only about 1 ft. below the spillway crest. Under these conditions, the pressure on the new section is, of course, extremely severe. While the flat slope of the face seems to relieve this pressure very well, the additional factor of safety provided by the rails has seemed worthwhile.

Work began on this construction in February, 1935, and, because of very favorable weather during the early spring months, was completed in May. On June 1, the reservoir was full, about $1\frac{1}{2}$ ft. of water running over the new spillway for several days; and almost the whole populace turned out to watch the sight that ended Creston's emergency.

Rehabilitation of System

The first months of operation disclosed the fact that the entire system was in need of a general rehabilitation. In 1917, the old company had made extensive improvements at the pumping plant, but since that time maintenance had been sadly neglected, with the result that much of the equipment required reconditioning.

In view of the fact that relief labor was available, the board felt that it was an opportune time to recondition the entire system. It was not necessary to replace any of the treatment or pumping equipment but all of it was in need of a thorough overhauling. Accordingly, a rehabilitation plan, including all equipment at the plant, was initiated. Additional equipment installed included two master recording meters, one a Venturi tube, recording pumpage, and the other an orifice plate, recording the amount of raw water treated.

Sand and gravel were removed from all filter units because trouble was being experienced in obtaining good results in backwashing. It was found that half the brass rosettes had been blown out of the 2-inch cast-iron laterals because of corrosion. The laterals were all in good condition except at the points where the brass rosettes were screwed into the pipe, and there the cast iron was corroded so badly that half of the rosettes were gone and the remainder almost ready to let go. From these indications it was concluded that the corrosion was due to electrolytic action resulting from the contact of the two dissimilar metals. At any rate, it was necessary to install a complete new system of underdrains. The stone within the units was easily cleaned with caustic soda before replacing. It was impossible, however, to do anything with the sand on the outside so it was replaced and cleaned with sulfur dioxide which made it as bright as new. Finally, the building itself was partially remodeled, cleaned and painted. The work lasted for over a year and when it was completed, the equipment, piping and building presented an entirely different aspect.

During this period another crew graded and landscaped the six acres of ground surrounding the plant. Some additional land had been acquired and, with the exception of the lawn immediately surrounding the building, the old grounds also needed attention. Three years were spent on this work with the result that there now exists a beautiful water works park (Fig. 2).

A summary of the major improvements completed during the period includes the following:

1. Reservoir dam and spillway raised, doubling capacity of Summit Lake.
2. Ninety-five acres of land for additional reservoir site purchased because of raised lake level.
3. Lower two miles of Summit Lake fenced. Concrete markers set on property line at all corners.
4. Metal lath and plaster ceiling installed in plant office, engine room and tool room.
5. Filter room remodeled, including installation of metal lath and plaster ceilings and cement floors, overhauling and resetting of chemical tanks and painting of room from top to bottom.
6. Pumping plant building rewired in conduit and proper lighting fixtures installed.

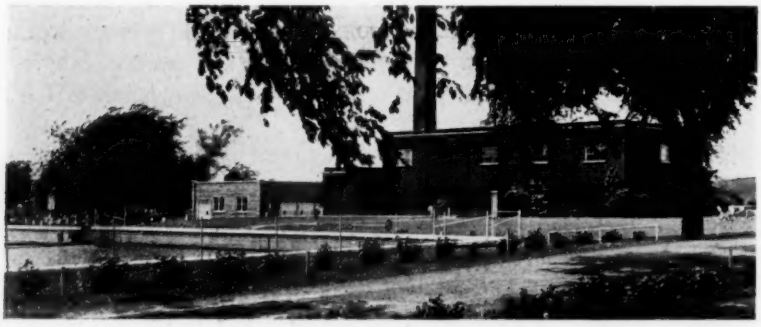

FIG. 2. General View of Water Department Grounds; showing settling basins and pumping plant

7. Building painted from top to bottom.
8. All pipes, pumps, engines and other equipment cleaned, overhauled and painted.
9. Boilers overhauled; boiler room cleaned and painted; and auxiliary steam line to pumps installed.
10. Exterior of brick chimney cased in concrete by guniting.
11. Master meters installed on 12-inch city discharge main and on 12-inch raw water supply line to basins.
12. Plant residence renovated.
13. Ice loading dock and equipment removed. Ice enginehouse remodeled into blacksmith shop.
14. Plant grounds graded and landscaped (2,000 trees planted).
15. Shoreline of Summit Lake, adjacent to dam, landscaped.
16. Brick garage, 40 ft. x 40 ft. in size, constructed.

17. Settling basins fenced.

18. Boat house for lake patrol boat constructed.

19. Boat landing for use of public and water works purposes constructed.

20. Underdrainage system in all filter units removed and replaced.

21. Filter sand and gravel in all units removed, cleaned, renewed and replaced.

22. Eight-inch pipe line installed with necessary valves to one low lift pump for filter backwash in order to wash filters without taking the necessary water from the high lift pump discharge as in the past.

23. Meter test equipment for checking accuracy of all meters over 1 in. in size installed.

At the time of purchase, the distribution system contained 35,000 ft. of small diameter galvanized iron pipe and 90,000 feet of cast-iron pipe. The minimum age of the galvanized pipe was 25 yr., so its rehabilitation or replacement constituted another problem which required attention. In addition, a section of the high value residential district was without adequate water for fire service.

The original improvement program did not provide for any work on the distribution system, but because of these circumstances and because the W.P.A. was willing to co-operate, it was decided that something could be done. Accordingly, a W.P.A. project which first took care of the low pressure areas in accordance with the recommendations of Harry Corcoran, Engineer for the Fire Insurance Rating Bureau, was initiated. When this was completed, elimination of the galvanized pipe was started. This work is still in progress and will require two years more to complete, work completed to date (November, 1940) being as shown in Table 1.

New Elevated Storage and Flocculation Facilities

The work either under way or completed as discussed to this point provided for all but three items necessary to make the system a first class one in all respects. The additional requirements were elevated storage in town, a cover for the open clear well at the plant and some method of mixing chemicals and raw water. Elevated storage was needed for better fire protection and the last two items were required by the State Department of Health as prerequisites for approval of the system.

No work toward the accomplishment of these improvements was effected until 1938, because all funds available on "pay-as-you-go" basis were being used to finance the above mentioned work under

W.P.A. In addition, the type of work required was not suitable for application of W.P.A. labor, so the project was being postponed purposely until the department was in a position financially to contract for the improvements. In the summer of 1938, however, P.W.A. funds became available, so the Board decided to issue sufficient revenue bonds to finance its share of the cost of the work. Contracts were therefore awarded, in the fall of 1938, for the construction of a 500,000-gallon elevated tank, for lining and covering the clear well and for constructing a mechanical flocculator.

No unusual problems were encountered in construction of the tank but in the clear well and flocculator, it was necessary to adapt the work to suit the particular plant layout. To understand fully the

TABLE 1

Cast-Iron Pipe Laid and Equipment Used to November, 1940*

PIPE AND VALVE SIZE	LENGTH OF PIPE LAID	IRON BODY GATE VALVES USED
in.	*ft.*	
14	94	1
10	331	6
8	5,067	11
6	2,555	12
4	15,929	104
2	16,322	49
Totals	40,298	183

* In addition to the iron-body gate valves, 15 tons of cast-iron fittings, 29 hydrants and 50 valve manholes were used.

reasons for the designs utilized, however, it is necessary to know something of the way in which the treatment plant is arranged.

As is the case in many plants, the Creston plant "just grew," adding new methods of treatment as they were developed. The plant was built in 1893, utilizing only plain sedimentation for treatment and steam for pumping. Consequently the basins, in four sections, were constructed out of doors, about 200 ft. south of the building. These basins measured 135 ft. x 368 ft. x 7 ft. deep overall and had a capacity of 2,500,000 gal.

Some years after the original construction, circular wooden-tub Jewell filters were installed in an addition to the pumping building. Next a 650,000-gallon circular clear well, 85 ft. in diameter and 20 ft. deep, was constructed out of doors between the basins and the build-

ing, using brick in the walls and concrete in the floor. Finally, in 1917, all old steam pumps were replaced, new boilers installed, modern rapid sand rectangular filter units constructed and the entire building remodeled.

As a result of this haphazard arrangement, all the improvements that were to be made had to be fitted into the set-up. The clear well, as might be expected, was leaking badly through the brick walls, although structurally it was sound. The concrete floor was also badly cracked and leaking. In addition, 16 columns which were to support the concrete slab cover had to be carried through the old floor in order to obtain adequate bearing for the footings. It was necessary, therefore, to place a new floor, and, to stop the leakage through the brick walls, to resort to guniting. The new structure was covered with a 7-inch concrete slab on which was placed 24 in. of earth and, finally, blue grass sod. Careful tests since completion have disclosed no leakage.

The design and arrangement of the flocculator involved many problems. It, of course, had to be placed either in or near the settling basins and, therefore, 200 ft. from the building. The flocculator mechanism desired required a compartment 12 ft. in depth, whereas the basins were only 7 ft. deep. If, then, the mechanism was to be placed in the basins, it would be necessary to go 5 ft. below the elevation of the basin floor. Then too, a detention period of several days, after the addition of chemicals, would not be necessary with flocculation, so that plain sedimentation could be utilized prior to mixing.

The problem of conveying the chemicals to the rapid mix at the flocculator, however, was the most difficult of all the problems. The use of dry feed equipment at the mixer would have necessitated either the construction of chemical storage space at the flocculator, thus rendering worthless the entire second floor of the pumping station building, or the transportation of the chemicals out to the flocculator as needed. Neither method was economical, convenient or efficient.

At the time, however, wet chemical feeds were in use and all necessary tanks, piping, and equipment for this process were already provided. In addition, the solutions would carry the chemicals from the building to the flocculator at the lowest possible cost and with a minimum of disturbance; the existing chemical storage space could be utilized; and the chemical solutions could be made up in exactly the same manner as was being used.

Under the circumstances, the use of the wet chemical feeds was, of course, the obvious solution to the problem. It was also, however, the most hazardous, because in order not to mar the appearance of the grounds, underground piping would have to be utilized. After a great deal of consideration, it was finally decided to attempt to use two 2-inch lines of cast-iron pipe. These lines were connected into a header, within the plant building, at the orifice boxes, and valves were so arranged that lime solution could be fed through one line and alum through the other, and the procedure reversed at will. In this way, it was felt, one solution would serve to neutralize the effects of the other. Both lines were provided with two "clean-outs" between the building and the basins. City water under 125 lb. pressure was also connected into the header, so that the lines could be flushed quickly and easily.

These lines have now been in service over a year, during which time they have been given weekly cleanings with a 2-inch circular wire brush and thorough flushing. After these cleanings the solutions have been reversed. As a result of these methods, the lines have been kept bright and clean without a sign of deposit or corrosion.

The flocculator was placed so that three basins could be used for plain sedimentation, with a two-day detention period, prior to the addition of chemicals at the rapid mix chamber. Thorough rapid mixing takes place in a chamber 5 ft. x 5 ft. x 11 ft. in size by means of two propellers direct-connected to a $\frac{1}{2}$-horsepower electric motor by means of a vertical shaft. The water then passes into a 11 ft. x 11 ft. x 37 ft. flocculation tank where it is agitated gently for 45 min. by 7-foot paddle wheels, chain-driven by a $1\frac{1}{2}$-horsepower motor, at a rate of 700 g.p.m. It then passes into the fourth basin, which has a detention period of 17 hr. at this rate. A maximum of 5 p.p.m. turbidity is maintained at the point where the water leaves this basin for the filters.

The use of plain sedimentation, because of excess basin capacity prior to flocculation, has proved an excellent plan. Savings in chemicals made during the year are due principally to this procedure rather than to the flocculator itself. Flocculation, of course, produces a much better water but, in itself, has made possible but a small chemical reduction. With raw water turbidities of less than 100 p.p.m., the reduction by sedimentation is, of course, much less than when raw water turbidities are high, but even with raw turbidities as low as 50 p.p.m., some reduction takes place, the average in this range

being from 10 to 15 p.p.m. It is at high raw water turbidities, however, that the real savings become apparent. Raw water turbidities of 1,200 p.p.m. can be reduced to 200 p.p.m., which means an important reduction in alum dosage. During the past year, turbidity entering the flocculator has never exceeded 250 p.p.m. while turbidities of 1,200 have existed in the lake. This use of plain sedimentation is the only novel feature in the installation of the flocculator and it is due entirely to the fact that the existing basin capacity was so much larger than would be needed for coagulation

TABLE 2

Turbidities of Creston Water Supply at Lake and Entrance to Rapid Mix Chamber, Showing Typical Results of Pre-Sedimentation

LAKE	ENTRANCE TO RAPID MIX	REDUCTION BY PRE-SEDIMENTATION	
p.p.m.	*p.p.m.*	*p.p.m.*	%
240	170	70	29
280	210	70	25
260	180	80	31
120	115	5	4*
130	130	0	0*
85	85	0	0*
110	25	85	77
140	85	55	40
190	100	90	47
140	75	65	46
1,200	125	1,075	90
800	150	650	82
950	230	720	76
55	38	17	31
50	37	13	26

* Winter readings—basins frozen, no reduction.

after flocculation. It has, however, in the first year of use meant a sizeable saving in chemicals as well as an effective aid in producing uniform operating conditions.

Table 2 gives the results attained at various periods during the year. It is interesting to note that during the month or six weeks in which the basins are frozen over, no reduction takes place, but that at all other times during the year, reduction is at least 25 per cent at low raw water turbidities and as high as 90 per cent when turbidities are high.

Summary

This, in brief, is a résumé of what Creston, Iowa, has been doing about its water supply to avoid repitition of the emergency conditions of 1934. The improvements made have given the city a first class water system approved by the State Department of Health. It now has adequate storage sufficient for many years to come and a completely reconditioned system.

Of as much importance as these physical improvements, however, has been the improvement in public relations. The troubles of 1934 focused attention on the water works and, as a result, it was realized that all of its actions would be observed critically. Public sentiment had been bitter and with only a small majority in favor of the purchase, the situation was virtually "charged with dynamite."

Accordingly, the new administration adopted a policy of keeping the community fully informed. In newspaper stories, by "open house" days at the plant, by construction progress reports, information concerning activities, together with the reasons for each step, was made public.

Each member of the organization from the stock clerk to the plant engineer, did his or her share in selling the system to all with whom they came in contact. Service was stressed, and complaints were carefully investigated regardless of how unreasonable they might appear on the surface. Service work such as shutoffs and turn-ons were taken care of by courteous and efficient men at the hour desired by the consumer. All were waited on promptly and pleasantly when they came to the office, regardless of whether they came to pay a bill or register a complaint.

This program has been effective. Gradually, the opposition has been converted; and, today, there are few, if any, who are not convinced that the purchase of the old system for $185,000, and the improvements made costing $175,000, representing a total investment of $360,000, have proved to be, by far, the cheapest and best solution to the problems of water supply which became so apparent in 1934.

Investigation of Canadian Water Supplies

By Harald A. Leverin

IN 1934, the Bureau of Mines of Canada initiated an investigation of the quality of Canadian waters used or available for industry and for civic supply. Since that time, the survey has led to the collection of a vast amount of information, and this material, through June, 1940, has been published in five "Interim Reports," which have included, among other things, the two maps presented with this paper.

The procedure of investigation has comprised: (1) sampling and complete analysis of surface waters of industrial importance; (2) sampling and partial analysis of civic water supplies; and (3) procurement, from manufacturing concerns consuming large volumes of water, of data covering problems arising from the quality of water used in their processes. In this work, the Bureau has used a portable laboratory to enable its investigators to make field analyses and tests, at the time of sampling, of those constituents and characteristics which would disappear or change on standing.

It has, of course, been essential that collections and analyses of each source be made at as short intervals as possible to insure obtaining a true average of the quality of each body of water. In the Quality of Waters Division of the U. S. Geological Survey water supplies are usually sampled periodically throughout the year and a composite of daily samples of each month made and analyzed. This has not been practicable in Canada; instead, it has been necessary to make complete analyses of surface water samples from lakes and rivers of industrial importance, collected at the key stations at high, mean and low gage.

A paper presented, in part, on March 27, 1940, at the Canadian Section Meeting, London, Ont., by Harald A. Leverin, Chemical Engineer, Division of Industrial Minerals, Bureau of Mines, Department of Mines and Resources, Ottawa. The paper consists, in part, of excerpts from Interim Report No. 5 of the Bureau of Mines.

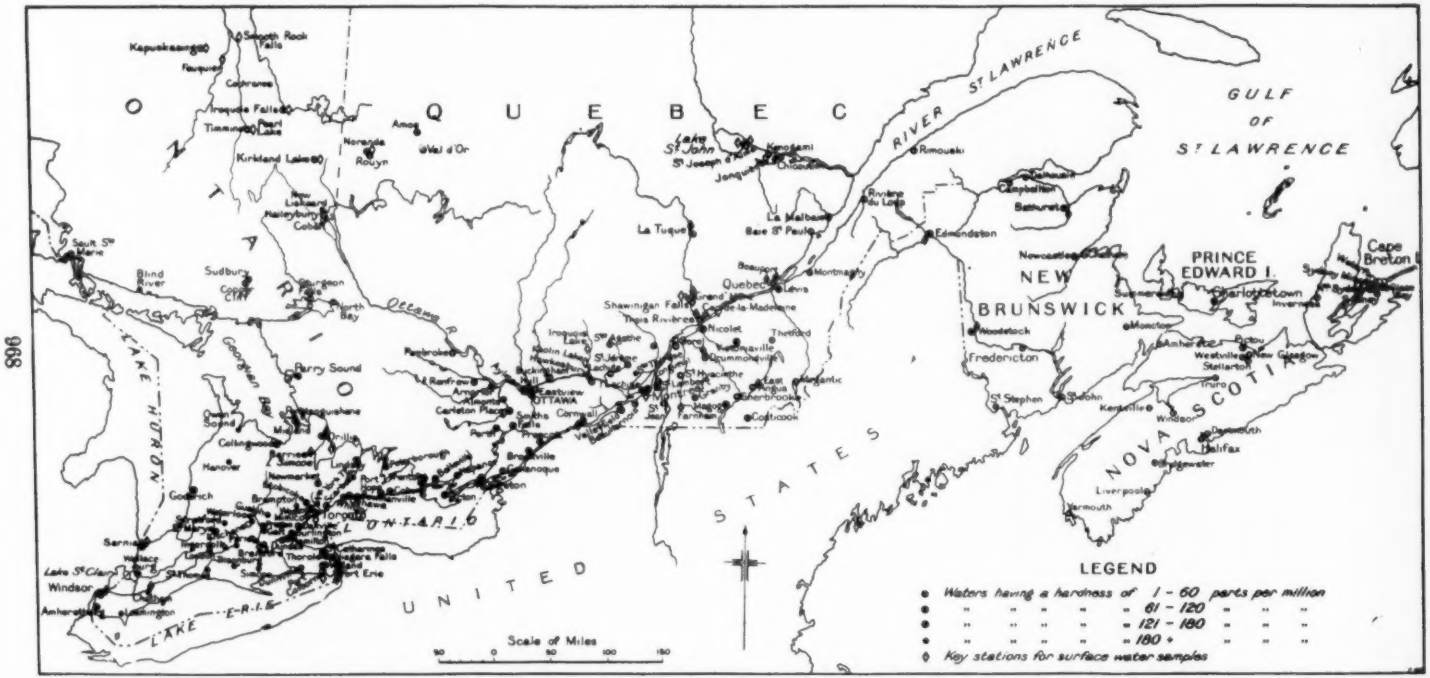
ONTARIO
QUEBEC
RIVER St. LAWRENCE
GULF OF St. LAWRENCE
NEW BRUNSWICK
PRINCE EDWARD I.
NOVA SCOTIA
Cape Breton
Fredericton
Ottawa R.
LAKE HURON
LAKE ERIE
Lake St. Clair
UNITED STATES
Scale of Miles
LEGEND
Waters having a hardness of 1 - 60 parts per million
" " " " = 61 - 120 " " "
" " " " = 121 - 180 " " "
" " " " = 180 + " " "
Key stations for surface water samples

FIG. 1. Eastern Canada; showing hardness of the chief civic water supplies

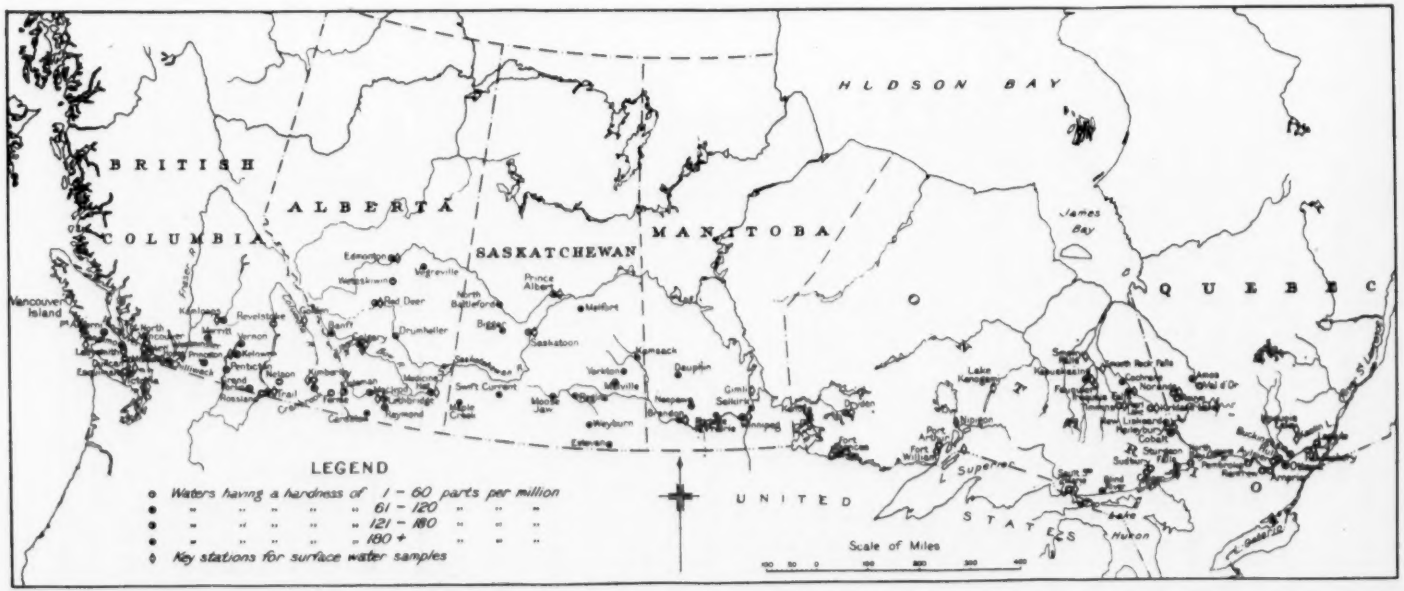

FIG. 2. Western Canada; showing hardness of the chief civic water supplies

Surface waters have been sampled with a device consisting of a brass cylinder of about one-gallon capacity, which, with both ends open, is lowered into the water to the desired depth and closed by a tug on the rope. What is important for field analysis is that, in this way, no air from the sampler or elsewhere can come in contact with the sample. In the field are determined the amounts of dissolved gases, oxygen and free carbonic acid, the hydrogen ion concentration, and the temperature. Temperature is recorded to permit determination of the degree of saturation of the dissolved oxygen.

TABLE 1

Number of Places and Populations Served by Waters Investigated

PROVINCE	NUMBER OF PLACES	POPULATION SERVED	
		Thousands	Percentage of total population
Eastern Canada			
Nova Scotia	20	188.9	36.8
New Brunswick	12	112.1	27.5
Prince Edward Island	2	16.1	18.3
Quebec	44	1,634.2	56.9
Ontario	85	1,833.8	56.7
Total	163	3,785.1	53.2
Western and Northern Canada			
Northern Ontario and Quebec	24	203.5	53.3
Manitoba	7	316.2	44.5
Saskatchewan	14	165.0	17.7
Alberta	13	207.9	26.9
British Columbia	30	436.6	58.2
Total	88	1,329.2	37.5

By June, 1940, 714 samples had been collected and analyzed, about 200 of these being from lakes or rivers of importance for industrial supplies. More than 500 samples were from civic supplies, those in eastern Canada being from cities or towns having a population of 3,000 or more and those west of Sault Ste. Marie, from cities or towns of a population of 2,000 or more. The sparseness of population in western Canada made this lower limit advisable.

The investigations here reported cover all of Canada except northern British Columbia, and the Yukon and North West Territories. In the absence of a sufficient number of analyses of samples, taken at set intervals, and of detailed investigatory work, the entire investigation, thus far, may be regarded as a preliminary survey of the more important industrial waters of Canada.

In the five Interim Reports, previously mentioned, are contained tabulations of the results of the complete analyses of surface waters, and of the partial analyses of civic water supplies, where total hardness, calcium and magnesium hardness and alkalinity were determined. Due to frequent requests for more complete analyses, the following determinations have, since 1938, also been made: color, total dissolved solids dried at 110°C., silica, iron, bicarbonate, sulfate, chloride and nitrate.

Table 1 summarizes information on the number of places served with the waters investigated in each province as well as the population served and the percentage of the total province population served.

As shown on the maps, the hardness scale chosen was that adopted by the U. S. Geological Survey. This scale was particularly desirable because many of the waters investigated were international.

Because standardization of methods of analysis, standard methods of reporting analytical results, investigation of the adaptability of such, and the devising of new methods of analysis, as occasion arises, are essential if uniformity in laboratory reports is to be attained, a committee to deal with these matters was appointed, in 1935, by the Canadian Public Health Association and the council of the Canadian Institute of Chemistry. Thus, "The Committee on Water Standards" has contributed in no small way to the literature on the chemistry of waters, has made many recommendations of standards and has issued yearly progress reports. The Committee works in close co-operation with the Joint Editorial Committee of the A. W. W. A. and A. P. H. A., which publishes *Standard Methods of Water Analysis.*

A very essential part of the reports of this investigation is the tabulated results of the analyses made. These can be obtained upon application to the Bureau of Mines, Dept. of Mines and Resources, Ottawa.

Auxiliary Water Supplies for Fire Protection

By A. C. Hutson

AN AUXILIARY supply for fire protection may be considered to be any auxiliary or emergency water system of sufficient capacity to be valuable for fire service. The most important auxiliary supplies for fire service, however, are those installed exclusively for that purpose. Many cities, including such large ones as New York, Boston and San Francisco, have installed extensive high pressure fire service systems; and many industrial establishments and quasi-public institutions have provided special fire supplies.

Such private auxiliary systems have been of interest to water works men for years, first, because of the possibility of their lessening materially the income of water suppliers, and more recently because of the danger of pollution of domestic supplies through cross-connection.

In regard to this inter-relationship between public water supplies and independent fire systems, it is interesting to study the conditions which introduced the necessity for the auxiliary supplies. Prior to the beginning of the Twentieth Century, little attention was paid to the full needs of fire protection when water systems were designed. Hydrants were installed, but they were often small and widely spaced, and the use of four-inch and smaller pipe was common practice, even in high value areas. It was common practice, too, to close gate valves, and leave a section without water, when taps and extensions had to be made; and there are known cases where an entire system was left without water while changes or additions to the piping system were made. Many items affecting the reliability of continuous service had not been properly studied, with the result that from time to time

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A paper presented on March 27, 1941, at the New York Section Meeting, Syracuse, N. Y., by A. C. Hutson, Assistant Chief Engineer, National Board of Fire Underwriters, New York City.

there was a serious decrease in supply, if not a complete failure. A remedy for this situation was of vital importance to the protection of industrial plants and businesses in general, which by that time were well on their way toward a complete change from the small individual factories and stores to large corporations housed in buildings which, with their contents, were valued at millions of dollars.

Prior to the beginning of the Century, too, buildings were constructed largely of readily burnable materials. This was prior to the introduction of the work of the National Board of Fire Underwriters in urging the adoption of building codes which would require fireproof construction; and before the work of that group on fire prevention standards.

Inadequacy of Fire Departments

All of these were contributory reasons for the introduction and use of auxiliary water supplies for fire protection, but the controlling factor in the situation, no doubt, was the status of the fire departments of that period. Before the introduction of the automobile fire engine in about 1913, fire departments, except in the larger cities, had few steam fire engines and so had to depend largely upon streams direct from hydrants. This practice necessitated short hose lines and a local distribution system of high delivery capacity as well as one capable of sustained pressure, and such requirements were seldom met, even around the principal plants. In addition, automatic sprinklers became, almost necessarily, the principal form of protection, and they required a water system which could deliver large quantities of water and still maintain suitable working pressures.

Fire departments, in many industrial areas, were at this time operating largely on the call basis, a modification of the older volunteer fire department scheme. Many of the men, because of their occupation, were also members of an organized fire brigade of the industrial establishment. It was, therefore, not uncommon for fires in these plants to be handled entirely by the plant fire brigade, and no call to be sent in for the municipal fire department.

These conditions served as an example for newly started industries, with the result that auxiliary or private water supply systems, and private fire brigades, were considered as one of the fundamentals of fire protection for any large establishment, even including stores.

Development of Fire Protection Methods

A review of the past 35 years, which cover the period in which the National Board of Fire Underwriters has maintained an engineering organization which has been reporting upon the water supply systems of the larger cities of the country, will show that the members of the American Water Works Association have become keenly alive to the necessity of adequate and reliable fire protection. A comparison of supply works and of distribution systems as they were in the early part of the century with conditions today shows that the recommendations made to increase fire flow and reduce the probability of interruption of service have been followed to a very large extent. Probably one of the outstanding factors in this connection is the increased use of elevated tanks of large capacity.

Keeping step with these water supply improvements the fire departments of the United States have bought automobile pumpers, increased the number of companies, and substituted paid forces for volunteer and call organizations. It has been of even greater importance that fire department members, including those of volunteer departments, have recognized the need of knowledge of the best methods of handling fires. They know the value of automatic sprinkler systems and in all their training programs stress the need for assuring an ample supply of water at good pressures for sprinkler systems.

Because of these changed conditions, that is, greater adequacy and reliability of public water supply systems, increased number of hydrants of good size, a larger amount of powerful pumping apparatus in the fire department, better trained fire fighting personnel, improved building construction and more care in lessening hazards, the National Board of Fire Underwriters believes that any funds available for the installation of auxiliary fire protection systems of an extensive nature, such as a special high pressure fire main system, can be spent to better advantage in improving the domestic water system.

The value of the changes and the lessened need for an auxiliary supply are further indicated by the revision of the Standards of the National Board of Fire Underwriters for the Installation of Sprinkler Equipments. For years these Standards read "For a standard equipment two independent supplies are required," and further that "One or more connections from a reliable public water system of good pressure and adequate capacity furnishes an ideal 'primary supply.' "

The latest edition of these Standards published in July, 1940,* reads as follows:

"Every automatic sprinkler system shall have at least one automatic water supply of adequate pressure, capacity and reliability. The supply required will be influenced by the area, height and value of the property, by the occupancy, by construction features affecting the spread of fire, by the quality and ready availability of public fire department response, and in some cases by the exposures to the building. The necessity for a second supply will depend on various factors such as those mentioned above.

"A connection from a reliable water works system, of adequate capacity and pressure, is preferable as a single or a primary supply."

In conclusion, it may be said that fire protection supply, of an adequacy and reliability suitable for practically any occupancy, can be provided in a municipal water works system. That this is not true in every case is due in part to a lack of appreciation of the needs of such protection on the part of water works officials. This lack of appreciation is, however, fast disappearing. Installing an auxiliary supply for fire protection, involving as it sometimes does the further item of guarding against pollution, can in many cases be avoided by strengthening the public supply in the vicinity of a particular plant, or by erecting an elevated tank on the property. The questions of charges for readiness to serve, or the rate at which water can be sold may be involved. Judging from the past, it is believed that the obligation on the part of the municipality to furnish adequate fire protection will be so well recognized as to make auxiliary supplies unnecessary in many communities.

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* Page 8, Sec. 301, Standards of the National Board of Fire Underwriters for the Installation of Sprinkler Equipments, as recommended by the National Fire Protection Association (July, 1940). Copies obtainable at no charge from the National Board of Fire Underwriters, 85 John St., New York, N. Y.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets, ★[ ]★ is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R. Water Pollution Research (British); I. M.—Institute of Metals (British).*

PUMPS AND RELATED EQUIPMENT

The Pumping of Granular Solids in Fluid Suspension. HERBERT CHATLEY. Engineering. (Br.) **149:** 230 (Mar. 1, '40). Practice of pumping subdivided solids in air or water streams becoming increasingly important. Problem of horizontal transport more obscure than that of vertical lift. Some work shows that fluid friction of mixture not increased by solids if velocity is such that grains are kept fully in turbulent suspension. Elements of power consumption are: (1) lifting solid grains; (2) accelerating solid grains; (3) sustaining solid grains in mixture; (4) accelerating fluid; (5) overcoming fluid friction; and (6) compensating for loss of kinetic energy at bends, valves, etc. (Illustrative examples of vertical and horizontal conveyance solved.) Head losses for horizontal and vertical pipes cannot be added together for combined horizontal and vertical pipe because velocity requirements different in two pipes, and acceleration items must be reckoned with only once. In case of hydraulic conveyance in pipes, buoyancy of particles reduces energy of sustentation in ratio of buoyant weight to gross weight. Figures given indicate present low efficiencies largely attributable to effects of bends and inlets, or incorrect proportioning of fluid and solid. Possible efficiencies of 30% indicated; whereas in actual grain hoisting for ships, power consumption rarely less than 0.9 h.p. per hr. per ton. For pure lift of 50′ this represents efficiency of only about 5%.—*H. E. Babbitt.*

Characteristic Design Factors for Pumps. J. R. FINNIECOME. Engineering. (Br.) **150:** 464 (Dec. 13, '40). Application of general law of similarity to design of pumps and turbo machinery, and of dimensional analysis to test results, has been found of great importance. Applying Camerer's well-established fundamental formula, we obtain

$$n_s = \frac{n}{57.45} \frac{(Q)^{1/2}}{H^{3/4}} \cdot \frac{1}{\eta_p^{1/2}}$$

and, by introducing ratio of dimensions and velocities of runner, we obtain

$$n_s = 258.7 \left(\frac{b}{d}\right)^{1/2} \left(\frac{U}{C_0}\right) \left(\frac{C_m}{C_0}\right)^{1/2} \frac{1}{\eta^{1/2}}$$

in which n_s = characteristic speed no. (specific) for pumps; b = tip width of blade in radial-flow, or height of blade in axial-flow pumps; d = tip diam. for radial-flow or mean diam. for axial-flow pumps; u = tip velocity of runner for radial-flow or mean circumferential velocity for axial-flow pumps; c_o = theoretical velocity = $\sqrt{2gH}$; c_m = mean fluid velocity through annulus of impeller, η_p = pump efficiency; Q = flow in g.p.m. (Imp.); and H = total head in ft. per stage. Writer has combined both formulas in chart

which gives, at a glance, relationship of Q, head, specific speed, and ratios of $u:c_o$, $c_m:c_o$ and $b:d$. *Discussion. Ibid.* **151:** 95 (Jan. 31, '41). G. URE REID: Data given for 3 radial-flow examples compare favorably with details of corresponding commercial frames. Ratio $u:c_o$ and, therefore, d, tip diam., are on large side, but this may be to provide margin for impeller adjustment after test. Comparison also indicates that b, tip width, refers to width at outer diam., d, in line with Daugherty's treatment, based entirely on exit width. Considering that loss due to bend in pipe line does not occur so much in bend itself as in straight length following it, may be doubted whether velocity-head correction allowed in modern pumps is much more than artful dodge to claim higher efficiency.—*H. E. Babbitt.*

Specific Speed of Pumps and Turbines. J. R. FINNIECOME. Engineering. (Br.) **150:** 377 (Nov. 8, '40). Specific-speed number is generally regarded by many engrs. as mere factor, but in reality it incorporates essential factors influencing design of turbines and pumps. Chart indicating fundamental design ratios in relationship to characteristic speed no. enables one to determine, at a glance, corresponding ratios of dimensions and velocities. Actual ratios for optimum efficiency on basic design or types of pumps usually determined from test data, as other important factors, not actually incorporated in formula, influence performance. Common knowledge that successful designs generally based on test data.—*H. E. Babbitt.*

Power, Capacity and Efficiency of Pumps. W. F. SCHAPHORST. Ind. Eng. Chem.—News Ed. **18:** 658 (Aug. 10, '40). From chart given, either h.p. required, g.p.m. pumped, pumping head or pump efficiency can be detd. graphically when values of remaining 3 variables known.—*Selma Gottlieb.*

Dimensional Analysis of Centrifugal Pumps. *Editorial.* Engineering. (Br.) **150:** 371 (Nov. 8, '40). Principle of dimensional similarity has had its range of utility notably extended to problems of centrifugal pumps and turbines. Very interesting result of new knowledge has been use of scale models to predict performance characteristics of large pumps and turbines. Mfrs. of turbo machinery are less familiar than they might be with physics underlying performance analysis, or are uncertain of limitations and precautions necessary to obtain reliable results. Principal conclusion drawn from all test results examined is that efficiencies and pressure heads developed throughout family of geometrically similar pumps can be related by coefs. based on equivalent of Reynolds no. and dependent on nature of fluid-frictional losses associated with different types of flow. Detn. of numerical index of roughness, which must depend on size, shape and distribution of asperities, presents almost insuperable difficulties in case of actual machine and is practically impossible to predict for proposed design. Good deal more work in all directions, also, will be necessary before all inherent possibilities of dimensional analysis of pumps and turbines can be utilized with ease and confidence.—*H. E. Babbitt.*

Centrifugal Pump Characteristics. Their Derivation and Meaning. B. J. LYMER. Wtr. & Wtr. Eng. (Br.) **41:** 531 (Nov. '39). Wide gap between elementary theory of centrifugal pumps and known performance. Head generated by theoretical formula will be found considerably in excess of that actually obtainable, ratio being designated by coef. called hydraulic efficiency, which is nothing more than "factor of ignorance" because all of water cannot leave impeller at tip. Precise location of point of leaving will depend on channel form of exit. Precise shape of head-volume curve considerably modified both by form of impeller vanes and by proportions of casing. Volute-type casing unsuited to conditions where quantity small, relative to head. Feature of such curve is that it gives so-called self-regulating power characteristic. When handling liquids containing high percentage of solids, no. of blades must be reduced to min. and cross-sectional dimensions of impeller and

casing must pass solids of required dimensions. Such proportions produce marked change in appearance of characteristic. In attempt to find form of impeller passage more nearly approaching needs of apparent flow than is provided by conventional design, test run on ordinary, low-priced, commercial model taken from stock, without refitting, but equipped with experimental impeller. In test, pump operated at efficiency of 60% or higher, whereas under similar conditions, standard impeller attained max. of 57%. Use of log. scales at times advantageous in presenting test data, as rate of change designated by straight lines instead of curves.—*H. E. Babbitt.*

Packing the Centrifugal Pump. F. C. THORN. Ind. Eng. Chem. **31:** 929 (Aug. '39). Most important, yet least understood, fact regarding centrifugal pump packing is that it inevitably leaks. If contact between packing material and rotary shaft tight enough to prevent leakage, packing or shaft or both will be destroyed. Function of packing is to throttle leakage, not eliminate it. Leakage of fluid being pumped can be eliminated by use of liquid seal of different liquid. Other methods for minimizing leakage are: minimizing pressure differentials and shaft gyration; use of packing of sufficient depth; and selection of proper type packing. Ideal stuffing box packing should be sufficiently plastic to conform closely to shaft under gland pressure, but have ability to free itself from too close contact without destructive friction and temp.; should be inert toward sealing liquid, liquid pumped and shaft metal; should be elastic enough to absorb any shaft gyration not eliminated by design; and should lose volume slowly so as not to require frequent renewal. Rubber alone is not satisfactory packing material; rubber-fabric types are better but principally used for end ring in set of braided packing, and then only under special conditions. Braid packings practically standard for centrifugal pumps; cheap and easy to mold in field. Made as single 8-strand braid, multiple with 12, 16 or 24 strands composing several braids, and modifications of these two with special binding strands. Rubber as binder satisfactorily durable but has tendency to heat up and seize. Usual binder is semi-solid fat or wax with liberal dusting of graphite; properties help counterbalance certain pump maintenance errors. Most common packing for general (chemical) service is 8-strand chrysotile asbestos yarn with binder of petrolatum or petrolatum-animal fat plus graphite. Chief disadvantage of braids is tendency to lose binder at low leakage rates. Plastic packings are mixtures of loose asbestos fiber, graphite and binder, sometimes with metal particles. In some ways better suited to operation at low leakage rates but harder to install than braided form, though coil of loose material now available. Metal foil, usually alloy lead, aluminum or copper, is used as packing, either shredded and bonded with rubber or other solid binder, or as broader strips, twisted, rolled or folded with simultaneous introduction of grease and graphite. Very durable and with proper care may last lifetime of pump. Not quite as close fitting as previous types and has been used more for oil than for water, though injecting graphite grease improves tightness for water service. Does not seize or abrade, but is costly, not readily prepared in field, and attacked by corrosive liquids.—*Selma Gottlieb.*

Building Big Pumps Better Earns a Bonus. ANON. Eng. News-Rec. **125:** 341 (Sept. 12, '40). Appreciation of advantages of high efficiencies in large pumps on Colorado R. aqueduct led to long series of model tests and offering of cash bonuses for efficiencies above that stipulated. 5 pumping plants will ultimately have 9 pumping units each, lifting water total of 1,616′. Initial installation consists of 3 units at each plant. Specifications required each unit to deliver not less than 200 ft. per sec. with efficiency of at least 88%. Pumps are vertical shaft, centrifugal volute type, without guide vanes, direct-connected to 4,300, 9,000 or 12,500-h.p. synchronous motors. Every known refinement used in making efficiency tests. Speed of rotation measured with

cathode-ray oscilloscope and discharge determined by salt-velocity method. Latter complicated by fact that turbulence was inadequate for satisfactory salt distribution. Artificial agitators overcame difficulty. Dicharge measurements checked by Venturi and by using reservoir as measuring tank. All pumps met specifications. Prototypes did not develop efficiencies quite as high as had been predicted from model studies. Motor losses averaged less than 3%.—*R. E. Thompson.*

Automatic Control for Pumping Stations in Kirkland Lake, Ont. F. G. BROWNE. Can. Engr. **78:** 12: 21 (Dec. '40). Description of 2 fully automatic pumping stations, one for sewage and other water supply booster station. Latter is provided with centrifugal pump driven by 30-h.p., line-start motor and pump of same characteristics driven by gasoline engine. Capac. of each pump is 750 g.p.m. at 40 lb. boost in pressure, and both take suction from low pressure (30–40 lb.) main fed by Gull Lake Sta. Protection is provided against operation of pumps with no pressure in suction by pressure switches which open control circuits when pressure drops below 5 lb. per sq.in. In event of power failure, relay, in series with operating coil in line-starter, opens and connects 6-v. battery circuit of engine, which, by series of small relays and contractors, operates starting motor and automatic choke. Equipment is housed in small bldg. heated with 2,000-w. air heaters. Station is visited by foreman once each day.—*R. E. Thompson.*

Dual Diesel Power Pumps. ANON. Am. City. **55:** 12: 58 (Dec. '40). Bourne, Mass., and 3 other communities lost water supplies during hurricane in '38 due to failure of power lines. To avoid repetition, 2 independent diesel engines driving 800- and 400-g.p.m. pumps have been installed. Larger diesel is started by electric-driven compressor supplemented by small gas-engine-driven unit on another compressor. Smaller engine is started by built-in gas-starting engine turned over by hand. Even small electric fuel pump for moving fuel oil from supply tank to gravity feeder tank supplemented by hand pump.—*Arthur P. Miller.*

Automatic Diesel Units Cut Down Operating Costs. GEORGE B. BAILEY. W. W. Eng. **93:** 72 (Jan. 17, '40). 5 yr. of continuous, uninterrupted operation of fully automatic diesel pumping station at North Easton, Mass., has resulted in complete satisfaction and $2,450 per yr. savings. Units (2) have capac. of 600–800 g.p.m., approx. 110 mil.gal. pumped annually. Oil consumption for lubrication averages 1 qt. per day, cost of fuel and oil combined less than $5 per mil.gal. Multiple units desirable and careful eng. application keynote of success.—*Martin E. Flentje.*

Transportable Emergency Pumping Sets. ANON. Engineering. (Br.) **149:** 150 (Feb. 9, '40). 3 semi-portable emergency diesel pumping sets have recently been completed for water works dept. of City of Sheffield. Are intended primarily for air raid precaution service, with principal purpose of providing an adequate self-contained emergency pumping installation to cover first-order risk. Sets coupled to branches of inflow and delivery mains and, therefore, available for immediate and continuous operation. Have been designed to be capable of being removed as complete units, or can be quickly dismantled for transport by truck. Each plant completely self-contained and capable of continuous operation requiring merely making of connections to inlet and delivery pipes of pump and corresponding pipes of water works.—*H. E. Babbitt.*

The Development of the Kaplan Turbine. J. R. FINNIECOME. Engineering. (Br.) **150:** 381 (Nov. 15, '40). In 1912, Kaplan proposed use of automatic adjustable runner blades to improve efficiency at partial loads. First commercial turbine was installed in Europe in 1925 and in America in 1928. Sufficient data now available to predict performance of full-scale runners from model tests. Kaplan turbine usually operates at comparatively low head. Gives high efficiency and very flat

power-efficiency characteristic and has high characteristic speed no. Characteristic speed has been expressed as

$$n_s = n\frac{\sqrt{N}}{H^{5/4}}$$

in which N = b.h.p.; H = effective head, in ft.; and n = speed, in r.p.m. Introducing ratio of blade length, L, to mean diameter, D_m, following modified formula obtained:

$$n_s = 258.7\left(\frac{L}{D_m}\right)^{1/2}\left(\frac{u_m}{c_0}\right)\left(\frac{c_m}{c_0}\right)^{1/2}\eta_T .$$

in which u_m = mean speed of runner, in ft. per sec.; c_o = velocity based on theoretical head = $\sqrt{2gH}$; c_m = mean axial velocity; and η_T = turbine efficiency. (Charts for solution of formula shown.) Two well-known formulas generally applied in determination of full-scale efficiency from experimental data on models. They are Camerer formula

$$\eta_T = 1 - (1 - \eta_0)\left[\frac{1.4\sqrt{d_0} + \sqrt{K_d}}{1.4\sqrt{d_0} + 1}\right]$$

and, the Moody formula

$$\eta_T = 1 - (1 - \eta_0)[K_d^{1/4} K_h^{1/10}]$$

in which, d_o = tip diam. of model turbine; η_o = turbine efficiency of actual model turbine; $K_d = \frac{d_o}{D}$ $K_h = \frac{h_o}{H}$; D = tip diam. of full-scale turbine; H = head of actual runner; h_o = head of model runner; and η_T = turbine efficiency of full-scale turbine. Chart shows that in all cases Moody formula gives full-scale efficiencies higher than Camerer's values.—*H. E. Babbitt.*

Experimental and Theoretical Investigation of a Turbine Foundation. S. Vesselowsky. Trans. A. S. M. E. **7:** 2 (June '40). Paper contains results of study made on turbine foundation for purpose of elucidating conditions which favor building up of excessive vibrations when unit is in operation. Structure studied was steel framework supporting concrete table with a turbo-generator erected on it. Experimental part consists of dynamical loading of structure and determination of its elastic constants. Theoretical treatment of problem consists of determination of frequencies and modes of natural vibrations by analytical methods. Comparison of theoretical results obtained with experimental findings is made. Results of study indicate that vibrations of turbogenerator on its foundation, for units of conventional design, can be treated as vibratory motion of a deformable body supported by a system of massless springs. Analysis of factors controlling vibratory motion of a turbogenerator on its foundation clearly shows that many recommendations of various authorities on turbine foundations are illogical. Resonance, which should be carefully avoided, is determined by elastic properties of structure and by masses and their distribution. Adherence to any arbitrary limiting value of static deflection or stress, as prescribed by some authorities, is by no means measure of safety or condition for success. Other authorities prescribe to design various portals of foundation structure in such a way that their individual critical frequencies should be identical. This consideration can be completely omitted. These same experts insist on separation of turbine foundation from common foundation mat of a power-house. In opinion of author, such separation is also unnecessary and can create great difficulties with piping. Influence of various details of machinery can be very great. For instance, if "rigid connection" between turbine and condenser were to be replaced by expansion joint, usual in Europe, immediate result would be substantial rise of vertical frequency (1,735 cycles per min. in case analyzed) due to elimination from vibrating system of very important mass.—*Homer Rupard.*

Steam Turbine Governors. R. J. Caughey. Trans. A. S. M. E. **62:** 3 (Apr. '40). Governing requirements for steam turbines, for stability and safety of operation, can be determined by mfr. Requirements vary with type and size of machine. Characteristics of governing

mechanisms to suit user's system and load cannot be determined readily by mfr. Governing characteristics will have effect on system stability. Entire paper is intended to aid purchasers to determine and state governor characteristics for particular unit that will best fit his system. Discusses in detail general principles of governing, governors, and their limitations as speed indicators and governing mechanisms and their limitations due to regulation and rapidity of load changes, protection of steam turbine against overspeeding, problems encountered in design of superposed steam turbines and tentative specifications for steam-turbine governing mechanisms. Steam-turbine mfrs. in past have asked users' groups to discuss governing requirements. Recently tentative governing specifications have been drawn up for hydraulic power units and these are being used as basis for steam-turbine governing specifications. Sensitivity is limited to a 0.04% speed change, with governor response with not more than 0.02% speed change. Droop shall be adjustable from zero to regulation of governor. Regulation shall be adjustable from 2% to 6%. Stability shall be such that governing mechanism can position steam valves without sustained oscillation of valves. Overspeed shall not exceed 110% upon loss of full load. Response shall be such that for a 6% governor regulation, steam valve lag will be not more than 20% of full stroke when instantaneous load change does not exceed 50% of full rated load. Speed adjustment from 98% at no load to 102% at full load shall be possible. Load limit shall be adjustable.—*Homer Rupard.*

The Lubrication of Steam-Turbine-Driven Electric Generators. F. J. COWLIN. Jour. Inst. of Mech. Engrs. (Br.) **143:** 2 (May '40). Primary function of lubrication system to supply bearings with adequate amt. of suitable lubricant to form pressure film which supports loads to which they are subjected. Quantity of oil needed solely for lubrication small, but temp. conditions and use of lubricant to keep temps. of bearings low enough requires large quantities of lubricant and means for circulating and cooling it. Tanks must be large enough to furnish sufficient cooling, and designed to eliminate entrained gases and other impurities. Coolers provided when heat to be dissipated is large. Thinness of pressure film in bearings requires that particles of foreign matter be removed from oil. On all except small units, lubricating oil pumped to pressure high enough to operate servo-motors which control governing mechanism. Continuous-duty demands from large units require installation of purifiers, piped up so that lubricant can be purified while unit in operation. Special high pressure pumps used on large units to force oil into bearings before unit is started, to reduce power required to start unit rolling. Two general types of oiling systems in use. First is single system arranged to serve only one unit. This is usual system. Design formulas for determining quantity and quality of lubricant for bearings discussed and explained with group of diagrams. Pumps for lubricants usually have to supply operating power for governing mechanisms and steam valves. Sometimes separate pumps are used, since different pressures are required. When one pump is used, lubricant supply passes through pressure reducing valve. Lubricating pumps, for sake of reliability must be integral part of main unit and be driven by direct and positive means. Worm and helical gear drives are used. Pump speed has been increased to simplify gear reduction problems. Gear pumps give high volumetric efficiencies but low mechanical efficiencies. Auxiliary pumps for starting service may be either steam or electric drive, arranged to start automatically if oil supply from main pump fails. Oil coolers, being heat exchangers of various forms, are used to extract heat that oil has removed from bearings. Design of coolers must provide for circulation that will result in high heat-exchange rates, must allow easy cleaning, must allow for expansion of tubes, and must be of materials that will stand service. Details of various types of coolers and arrangements illustrated and discussed.

Oil tank capacities should be sufficient to maintain reasonable life for lubricant. 20 changes per hr. may be satisfactory for small units but must be reduced to 6 or 8 for large units or highly refined oils. Strainers used to remove solids from oil. Tanks baffled to provide complete circulation and arranged for easy cleaning. Particular attention must be given to all piping to minimize fire hazards. Joints must be kept away from hot surfaces, where leaking oil could be ignited. Velocities in piping seldom more than 1 ft. per sec. So-called oil-resisting paints for tanks, and parts in contact with oil, should be used with care, since acidic oil will break down paint. Expts. with various fluids and gases to form lubricating pressure films discussed. Expts. with non-inflammable lubricants under way. Turbine oil must be highly refined pure mineral oil which will separate from and not form emulsions with water. Break-down of oil is from oxidation, caused by aeration, water contamination, catalytic effects, overheating, and electrolytic action. Each cause discussed in detail. Purif. commonly effected by centrifugal purifier, connected so that portion of oil constantly by-passed through purifiers. Heating oil to 135–160°F. will improve separating effect. Filters sometimes used to augment and improve work of centrifugal purifier. Process used in America known as "resting" consists of draining entire charge into settling tank and allowing it to stand for several months. Author concludes much yet to be learned regarding quant. relations governing operation of journal and thrust bearings. Oil pumps can be improved in mechanical efficiency. Oil-cooler design leaves much to be desired, particularly for cleaning and leakage. Fire risk has been reduced both by use of non-inflammable fluids and by care in piping design.—*Homer Rupard.*

Deep Well Pumping Unit at Wingham, Ont. ARTHUR C. LEWIS. Can. Engr. **78:** 12: 19 (Dec. '40). For first time in Canada, electric motor-driven deep well pump with auxiliary gasoline engine power unit connected at right angles to pump shaft through flexible drive shaft was installed recently at Wingham, Ont. Combination very compact, free from mechanical complications. Decided improvement over belt drive for auxiliary or emergency power. Pump is 7-stage, deep well turbine unit installed in 12″ well at depth of 60′ below ground. Capac. is 396 g.p.m. against head above ground of 190′. Static water level is 16′ and drawdown with pump operating at capac. is 30′. Pump efficiency is 80%. Normal drive is by 40-h.p., 60-cycle, 3-phase, 550-v., hollow shaft, vertical, line-start motor incorporated in pump head and operating at 1,760 r.p.m. Auxiliary power is derived from 6-cylinder gasoline engine delivering 50 h.p. at 1,800 r.p.m. To provide for combination drive, with elec. motor through vertical shaft and with engine through horizontal shaft, pump head contains right-angle gear drive, comprising pair of spiral bevel gears enclosed in cast-iron housing and provided with requisite anti-friction load and thrust bearings and clutch to disengage motor when engine is used. Pump delivers to elevated tank with bottom elev. 140′ above ground level.—*R. E. Thompson.*

A Rapid and Successful Method of Drying Flooded Motors. ANON. W. W. & Sew. **87:** 61 (Feb. '40). Steam heaters with built-in blowers used to dry coils in place at Buffalo. Canvas hood confined heat.—*H. E. Hudson, Jr.*

Pumping Plant at Spalding Water Works. ANON. Engineering. (Br.) **148:** 514 (Nov. 3, '39). Urban Dist. Council of Spalding takes water from wells at Bourne, 13 mi. away, supplying water to Bourne, Spalding, East Elloe, and Boston (total pop., approx. 59,300). Consumption approx. 316 mil.gal. (Imp.) for year. Static pressure in well may be as high as 29 lb. per sq.in. Although pumps are of positive reciprocating type, no open towers or reservoirs on distr. system. Air vessels fitted to pump discharge and bypasses always left open. Equipment of well and pumping station described in detail.—*H. E. Babbitt.*

DISTRIBUTION SYSTEMS—CONSTRUCTION AND MAINTENANCE

Modern Engineering Practice and Two-Inch Cast-Iron Pressure Pipe. C. D. Cox. J. N. E. W. W. A. **54:** 294 (Sept. '40). Increasing popularity of small-diam. cast-iron pipe demonstrated by growth in use from 700,000′ to 4,000,000′ within 10 yr. Increase due to unsatisfactory experiences with non-corrosion-resisting metal and weak-composition piping, mounting maintenance costs on small lines, and desire to standardize on all essential materials. 2″ pipe inadequate for fire protection service, but can be used if proper tie-ins made. 2″ main will satisfactorily serve 10–12 domestic consumers on a line 1,000′ to 1,200′ long. Shown that costs for 1 block of 6″ main with 48 services practically same as if served by 2-main system of one 6″ and one 2″ pipe. Modern mfg. methods have lowered cost and improved quality and strength of pipe. Complete line of small fittings and reducing fittings now available; joints have been improved and perfected; number of types now available. 2″ pipe usually shipped in 18′ lengths.—*Martin E. Flentje.*

Economic Pipe Size. B. R. Sarchet and A. P. Colburn. Ind. Eng. Chem. **32:** 1249 (Sept. '40). Economic pipe sizes for ave. conditions can be calculated by equations:

$D_i = 3.0\ q^{0.36} Z^{0.18}$
for viscous flow where $D_i > 1''$

$D_i = 3.6\ q^{0.4}\ Z^{0.2}$
for viscous flow where $D_i < 1''$

$D_i = 3.9\ q^{0.45} \rho^{0.13}$
for turbulent flow where $D_i > 1''$

$D_i = 4.7\ q^{0.49} \rho^{0.13}$
for turbulent flow where $D_i < 1''$

where D_i is pipe diam. in inches; q is flow rate in cu.ft./sec.; Z is viscosity in centipoises; and ρ is density in lb./cu.ft. Nomographs shown for graphical calculation from these equations. If cost conditions differ widely from ave., correction factor is $\left(\frac{8760}{h}\right)\left(\frac{C_1}{0.013}\right)\left(\frac{0.01}{C_2}\right)$, where h is hours of operation per yr.; C_1 is annual cost, in dollars, of 1′ of 1″ i.d. standard pipe; or $C_1 = (a + b)(F + 1)x$, where a is amortization expressed as decimal; b is maintenance expressed as decimal; F is factor for fittings and erection; and x is cost per ft. of 1″ diam. pipe. C_2 is cost per ft. of delivering energy per ft. of length. Correction factor is multiplied by q for viscous flow and by ρ for turbulent flow. Annual cost of unit length of pipe may be generalized as $C_3 D^n$, where C_3 is annual cost of 12″ diam. standard pipe in dollars per lin.ft.; D is pipe diam. in ft.; and n is slope of logarithmic plot of cost of pipe vs. diam. Annual cost of pressure drop for turbulent flow is $C_4 q \Delta P/L$ where C_4 is annual cost of supplying 1 ft.lb. of energy per sec. in dollars; q, as above; ΔP is pressure drop in lb./sq.ft.; L is length in ft. For viscous flow, cost is $\frac{40.8\ C_4 \mu q_2}{gD}$ where μ is viscosity in lb./(sec.) (ft.); and g is acceleration of gravity in ft./(sec.) (sec.).—*Selma Gottlieb.*

The Cost of Mains. D. R. Taylor. W. W. & Sew. **87:** 304 (July '40). Carefully detailed table for use in estimating costs of mains. Data broken down to work units and material units so that unit expenses at any locality may be substituted conveniently. Based on experience at Roanoke, and elsewhere in Va.—*H. E. Hudson, Jr.*

The Notebook as an Aid for the Maintenance of the Distribution System. Walther Ebner. Gas u. Wasser. (Ger.) **83:** 121 (Mar. 16, '40). Supervision of distr. system is put in charge of foremen, each one having his definite dist. Duties are thorough local knowledge, direction of tapping and repairs, search for leaks, maintenance of valves and hydrants, patroling dist., etc. To increase efficiency of foreman, he receives pocket-size six-ring notebook in which are bound general maps, detail drawings of layout of pipes at intersections, lists of addresses and phone numbers of work-

men and available auxiliary helpers, lists and descriptions of valves, hydrants, location of valve keys, lists of private water supplies, sheets for different reports, e.g., repairs, fires, needed improvements. All this tends to make an organization ready for emergency.—*Max Suter.*

Oxy-Acetylene Equipment Expedites a Water Main Repair. ANON. Eng. News-Rec. **125:** 693 (Nov. 21, '40). In Hammond, Ind., crack in 36″ cast-iron main under Calumet R. admitted raw river water, necessitating prompt repair. Temporary 24″ steel diversion line laid across bridge and two 36″ to 24″ steel reducers prepared for tie-in with main line. At night, when consumption at min., holes were cut in the two 36″ elbows in main line at river banks, water pumped out, and elbows severed by circumferential cut. Lead in bell-and-spigot joints of elbows then melted, elbows removed with block and tackle, and reducers tied in by means of couplings. Entire job completed and water flowing through diversion line early next morning.—*R. E. Thompson.*

Maps and Records. ALBERT R. DAVIS. Tex. W. W. Short School. **21:** 57 ('39). Importance of keeping records up to date cannot be overstressed. System of maps only 95% complete practically worthless. Includes outline of some of records kept in water dept. of Austin, Tex.—*O. M. Smith.*

Comparative Tests on Bell and Spigot Joints. HELLMUT GÖTTING. Gas u. Wasser. (Ger.) **83:** 513 (Oct. 12, '40). Additional tests made of bonding strength of aluminum wool, lead wool, sinterite (a spongy iron saturated with bitumen) and material called "Mundit." Effect of depth of filling the joint was studied. Strength increases with increasing depth of calked-in material. Aluminum found superior to lead, Mundit had least bonding strength. Same strength obtained by 20 mm. of aluminum, 25 mm. lead, 37 mm. sinterite and 60 mm. Mundit. Aluminum should not be used in excessive depth, as this reduces flexibility of joint. Aluminum must be stored dry and outside of joint must be protected from humidity by bituminous cover.—*Max Suter.*

Automatic Welding for Water Mains. ANON. Eng. News-Rec. **125:** 343 (Sept. 12, '40). Improvements to N. Y. C. distr. system include some 16,000′ of 48″ pipe formed by cold-rolling ½″ steel plate into semi-circular shape and automatic longitudinal welding by "Unionmelt" process developed by Linde Air Products Co., in which visible arc, sparks, spatter, smoke and flash are absent. Ave. overall cost, including laying, is $25 per ft., while few yr. ago, cost of type of pipe used approx. $20 per ft., exclusive of construction labor costs. Etched cross-sections of one-pass butt welds are illustrated. Welding speed is 18″ per min., with machine using 800 amp. at 32 v. Specifications require that test specimens develop ave. ultimate tensile strength of not less than 50,000 lb. per sq.in., be tested to destruction and break outside weld. Min. acceptable strength is 45,000 lb., with not more than 20% of specimens showing strength of less than 50,000 lb. Bend test consists of cold-bending through 180° around a 2¼″ diam. Pipe is subjected to hydrostatic pressure of 150 lb. per sq.in. in shop, during which welds are struck with 5-lb. sledge, and then pressure is raised to 300 lb. for 3 min. Pipe is then coated inside and out with spun coal-tar enamel. Completed main is tested in 1,000′ sections under pressure of 125 lb. per sq.in., maintained for 20 min. Max. leakage allowed is ¾ gal. per lin.ft. per day.—*R. E. Thompson.*

Precast Supports and Girders Carry 4-Acre Reservoir Roof. ANON. Eng. News-Rec. **126:** 20 (Jan. 2, '41). Precast concrete selected at Ventura, Calif., for supporting corrugated metal roof over 4-acre filtered water reservoir. Disastrous fire in wooden roof over res. in Berkeley swung decision to concrete. Res., built in '37, is concrete-lined excavation with capac. of 18.8 mil.gal. Irregular shape, roughly 340′ x 565′ in plan and about 18′ deep. Each roof column base carried on concrete pier 3′ square, cast in place after recess was

cut in 4″ concrete floor. 515 columns, 9,688 lin.ft. of girders, 8,487′ of struts and 36,224′ of purlins, all precast. Specifications required strength of 3,000 lb. per sq.in. in precast members prior to transportation and erection. Requirement was met on fifth day; ave. 28-day strength was 4,763 lb. Redwood strips, 2″ x 3″, set in purlins during casting and held in place with galvanized nails to serve as nailing pieces for galvanized metal roofing. Roof has central louvre above main roof level for entire length of res. Natural circulation set up by thermal induction between louvre and opening around outer edge. All openings screened with ¼″ mesh monel screening on redwood framing.—*R. E. Thompson.*

Standpipe to Water Tank Collapses Inwardly. S. B. CODE. Eng. Cont. Rec. **54:** 10: 19 (Mar. 5, '41). In '24, filter plant and elevated tank of 204,000-gal. capac. added to existing water supply system of Smiths Falls, Ont. Riveted steel standpipe to tank is 120′ high and 5′ in diam. Considerable difficulty experienced in preventing water in tank from freezing and, of different methods tried, use of steam from adjoining pumping station most successful. During severe cold weather in early part of Jan. of this yr., ice formed in tank and stand-pipe and structure has not since functioned. On Feb. 13, thawing was attempted by inserting live steam hose through manhole in base of structure. In 2 days, riser had been cleared up to within 12-15′ of base of tank. About midnight on Feb. 14, standpipe, with roar resembling explosion, which shook ground in vicinity, buckled and flattened through length of about 10 sections, tearing off tie rods. Vacuum may have been caused either by the condensation of steam or by a block of ice descending from the top to the bottom of the structure.—*R. E. Thompson.*

Improved Water Service at Stamford, Conn. ANON. Am. City. **55:** 10: 47 (Oct. '40). Sub-division of some country estates, and location of a new high school in Newfield Ave. section of Stamford, Conn., made essential supplying of city water to that area. Booster station and supplying pipes, as well as a new standpipe were constructed. Location of new elevated storage tank in high class residential dist. indicated special architectural treatment. Consisted of adding cornice, 10 tubular columns, with bases and caps, and two ornamental bands, all butt-welded. Tank roof is low-domed and self-supporting. One of columns contains ladder leading to catwalk inside cornice. Details arranged to that no unpleasant projections show on tank.—*Arthur P. Miller.*

Design for a Water Tower. WILLIAM EUGENE BLACKMORE. Wtr. & Wtr. Eng. (Br.) **43:** 13 (Jan. '41). [Award of Charles Hawksley Prize made to Blackmore for] design of water tower carrying covered tank, for urban water supply, with capac. of 150,000 gal. (Imp.). Bottom of tank 75′ above ground level. Ground below tower is clay, overlying rock 25′ below. Reinforced concrete selected because of clean and solid appearance and adaptability to any shape. Octagonal shaped tank chosen. Section selected for supporting column, shaped like broad cross, provided pleasant combination of shadows. Found to be more economical to take piers down to rock level than to distribute load over clay by means of raft. Such water tower would be suitable for erection in practically any environment.—*H. E. Babbitt.*

Elevated Tank Saves Power. ANON. Eng. Cont. Rec. **53:** 39: 28 (Sept. 25, '40). Tank of 208,000-gal. capac., 150′ high, recently installed in Perth, Ont. Prior to installation, pumps operated continuously as there was no storage on system. As result, wide variations in pressure, and pump repairs sometimes interrupted service. With tank in operation, pumps operated intermittently at constant rates, and pressure maintained between 60 and 65 lb. per sq.in. Pumping performed with off-peak power and saving thus effected will pay cost of tank, including interest, in 15 yr. Tank is equipped with Rustop cathodic protection system. Telemeter of chrono-

flow type, with graphic indicator, installed in pumping station, 1 mi. distant.—*R. E. Thompson.*

Russian Water Distribution and Sewerage Systems in Permanently Frozen Ground. V. P. Gesundh. Ing. (Ger.) **63:** 574 (Nov. 2, '40). About 47% of Russia and Siberia has permanently frozen ground. Water distr. and sewerage systems can be operated all winter in these lands if certain precautions are observed. Fundamentally, this requires that pipes be laid deep to have heat exchange only to ground, heat losses to the surface to be avoided. 10 ft. of depth considered necessary; pipes have to be embedded in 8″ to 12″ of gravel covered with 2 to 3 diameters of sand. On this is laid 16″ of clinkers and 8″ of clay. Remainder can be filled with frozen ground. In heavily frozen ground peat is also used for insulation. In dry non-aggressive soil cast-iron and welded-steel pipes can be used, but asbestos-cement pipes with elastic joints generally recommended. Concrete pipes have too great heat losses. In water distribution systems, pipes have to be small enough to allow 8 turnovers per day. In times of low consumption flow has to be increased by wastage; and water has to be preheated with waste steam, or otherwise, to keep outlet temp. at at least 4°C. Conduits of central heating systems or waste lines from laundries and similar industries can be laid near water line to keep them from freezing. Sewers have to be heated by passing warm air from buildings; sometimes even sewage has to be heated. Manholes built in wood to reduce heat losses.—*Max Suter.*

Studies of Frost Penetration. HARRY U. FULLER. J. N. E. W. W. A. **54:** 275 (Sept. '40). Report of detns. of ground temps. in Portland, Me., carried on for yr. beginning Sept. '35. Thermometers installed at 6″ intervals from 1′ to 6′ below surface; one set in gravel, one in clay. Snow removed from overlying ground to reflect conditions on roads. In gravel, frost began to go down on Nov. 27 and reached lowest point (45″) on Feb. 27 remaining there until Mar. 7, when ground began to thaw at bottom. Surface began thawing on Mar. 10 and on Mar. 16 last frost melted only 15″ below surface. In clay, surface frozen Dec. 15, and frost line then moved down to 48″ by Feb. 27; from this date moved upward until Apr. 3 when last frost disappeared. Gravel temps. much more responsive to air temps. than clay; under influence of same rising air temp. frost went out of gravel in week but took month in clay. Graph of cumulative daily temp. deficiency (difference between 32°F. and daily mean temp.) and frost line show good correlation, with, however, some lag as is to be expected. Frost chart prepared on which accumulated deficiency temp. line can be drawn, and probable depth of frost line then taken off chart. Chart used in Portland past year and found quite satisfactory.—*Martin E. Flentje.*

Depth of Frost Under Pavement. FRANK R. PRATT. Eng. News-Rec. **125:** 835 (Dec. 19, '40). Data presented on depth of frost under 9″ concrete pavement in New Brunswick, N. J. Pipe, ½″ in diam., laid flush with sub-grade surface, and temp. at bottom of slab measured by placing 1 junction of copper-constant thermocouple in pipe, which contained alcohol in lower part, and other junction in thermos bottle containing mixture of ice and water. Temp. read on sensitive galvanometer. Temp. on upper surface read with mercury thermometer. Air temp. obtained from recording thermometer, and water in main, 6′ below ground surface, gave some indication of temp. at that depth. Observations made for 4 wk.—min. temp. of atmosphere was —10°F. (few hr.). Lowering of temp. on underside of slab occurred about 24 hr. after sudden drops in air temp. Temp. gradient lines show that there is point 7′ below upper surface of concrete where temp. remains nearly constant at 45°F. Freezing line in temp. gradient graph crosses min. temp. line at nearly 5′ below upper surface. Low temps. of short duration, however, and frozen soil probably did not extend below 4′. Extension of temp. gradient line in concrete to meet frost line shows that frost might just pass through concrete 16.5″ thick.—*R. E. Thompson.*

Damage by Frost and Its Prevention in Distribution Systems. OTTO HANNEMANN. Gas u. Wasser. (Ger.) **83:** 403 (Aug. 17, '40). Statistics on damage caused by frost on distr. systems and hydrants in German cities during cold winter '39–'40 given. House connections not considered in report. Many breaks occurred even after thawing weather started. In some cities, high percentage of damage done at or near hydrants, but distr. mostly irregular. Causes mentioned: (1) pipes not buried deep enough, often on account of changes in the street grade; (2) freezing of water in hydrant when not correctly drained; and (3) lifting of hydrants by freezing of ground. Methods for prevention are evident. Recommended to check hydrants for drainage after use and to have hydrant riser smooth and embedded in sand to reduce friction on freezing of ground. Curves given show relation between penetration of frost into ground with temp. and duration of cold. Delay occurs between temp. in soil and that in air. Normal water content of soil can cause rise of about 1″ by freezing depth of 3′. Actual measurements show greater lifting of top, which is explained by the formation of ice lenses. These form in fine-grained soils where additional ground water can enter by capillary movement. On melting, ice lenses form soft ground which may cause additional damage to system.—*Max Suter.*

Control by Automatic Valves. ANGUS A. FULTON. Wtr. & Wtr. Eng. (Br.) **42:** 303 ('40). Automatic control devices may be classified as those for ordinary conditions, and those for emergency conditions. Requirements of first class met by valves known as altitude valves. To deal with emergencies, types of valves usually required are trip-operated, self-closing valves, check valves, and relief valves. Possible to calculate whether or not water hammer will occur. Found that all valves give far better results if, instead of closing at uniform rate, they close quite rapidly for first 70% of closing stroke and then take as much as 3 or 4 times as long for remainder. Float valves with pilot valve more sensitive than otherwise and have advantage that size of float can be reduced. Pressure-reducing valves of small size either of spring-loaded type or work on diaphragm principle. Most of larger valves of weighted lever piston type. Essential difference between pressure-relief valves and pressure-reducing valves is that latter open or shut as required by change in pressure on delivery side, whereas pressure-relief valves operate with variation of pressure on inlet side. Non-return and check valves used usually in connection with pumping. One of commonest applications is as foot valve on pump suction. Usual to put check valve on discharge side of pump to shut at instant that reversal of flow is to take place. No reason why slow-closing check valves, fitted with oil-filled dash pots, should not be used. Amount of fly-wheel effect provided in pumping sets has important influence on solution of such a problem. Small automatic pumping set should be shut down when water reaches top level in reservoir. To do this, altitude valve is inserted in rising main near res. Emergency self-closing valves brought into action by drop in or complete failure of pressure on downstream side of valve. Should be placed at frequent intervals along main. In most respects, needle type of valve satisfactorily fulfills normal requirements. Sluice valve has merit of being simple, clear waterway when open, and less expensive than needle valve. Rotary or plug valve is new type not often seen in water works practice, but no reason why it should not be used. Two recognized methods of bringing emergency valves into action are paddle and diaphragm. Both make use of mechanical trip to set closing method into motion. Diaphragm requires Venturi throat to provide necessary difference in pressure. Most air valves automatic in action and in water works practice, usually of ball type, but not without some serious faults. Not uncommon for valve to close before all air is exhausted. Best way to avoid faults is to use air valves with controlled closing. *Discussion. Ibid.* **43:** 31 (Feb. '41). F. KLOUMAN: If pipe can maintain supply under manual control, should do so under automatic control. Prudent course would be to to install self-closing

valve as near to source of supply as possible. If trunk main feeding service reservoir is designed to deliver max. ave. demand, then float valve controlling delivery *must* have unrestricted opening. Turbulent flow can have quite destructive effects on mushroom-stopper type of valve due to cavitation and erosion, if allowed to occur at wrong place. *Author's Closure:* Float valve cannot give exactly same results as obtained from manual operation. Self-closing valve at inlet end of long main of large diam. is not going to be complete success in limiting damage caused by burst. Should be several valves distributed along main. Reducing valves are makeshifts and it is only because they do their work cheaply that engrs. shut their eyes to their hydraulic shortcomings.—*H. E. Babbitt.*

Automatic Float Valves for Rangoon Water Supply. ANON. The Engr. (Br.) **170:** 344 (Nov. 29, '40). Valves to be erected on foundations adjacent to reservoir. Each in form of standpipe, including top float chamber. Two valve beats connected by mild steel spindle extended through guides to float chamber. Float, 6′ in diam., of bell type, open at bottom, and obtains buoyance from air trapped inside. Height of valve from bottom to top is 28½′.—*H. E. Babbitt.*

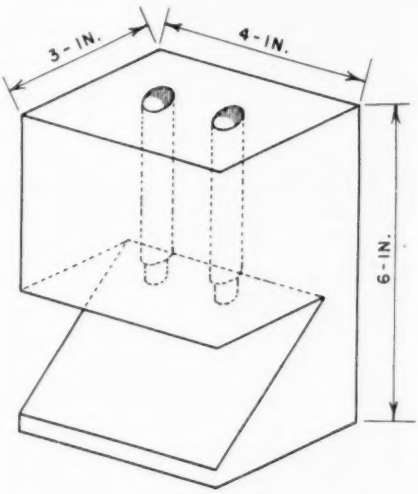
Pressure Reducing Valves. ANON. Wtr. & Wtr. Eng. (Br.) **42:** 378 (Nov. '40). Two operations in reduction of pressure by automatic pressure reducing valve: conversion of pressure energy into velocity energy and destruction of surplus or unwanted velocity energy. Two forms of valve now in use for pressure reduction: globe type seat-and-stopper valve either of equilibrium or double-beat design, or streamlined plunger type which presents complete break with earlier and conventional forms. In latter, flow passages deliberately designed to create disturbed flow conditions under high velocity; destruction of velocity energy necessarily accompanied by impact upon valve parts, and by eddy currents concentrated therein. In streamlined plunger valve, flow passages designed to give favorable flow conditions under all velocities. Both streamlined and seat-and-stopper valves will provide drop-tight closure—former, always; latter in equilibrium form only. Accepted governing device in each case is external ram or piston loaded to comply with specified outlet pressure, and operating under that pressure. Streamlined type has powerful recommendations. Where great latitude in performance is permissible and where no severe test of durability is involved, conventional pattern with its lower cost often justified.—*H. E. Babbitt.*

LABORATORY METHODS—EQUIPMENT AND APPARATUS

Slide Rule for Water Technology Calculations. A. A. HIRSCH. Ind. Eng. Chem.—Anal. Ed. **12:** 542 (Sept. '40). Special slide rule with arithmetic divisions spaced inversely according to $CaCO_3$ equivalent weights of various components solves directly various water technology calculations and furnishes close approximations to others. Applications include conversion of concentration units, detn. of $CaCO_3$ equivalents, lime and soda ash dosage, calculation of sodium by difference, ionic strength, dosage calculations of sulfuric acid to reduce carbonate, sulfite or sulfoglucosate for oxygen removal, amount of boiler scale, A.S.T.M. ratios, soap waste cost, quality of irrigation water and electrical conductivity.—*Selma Gottlieb.*

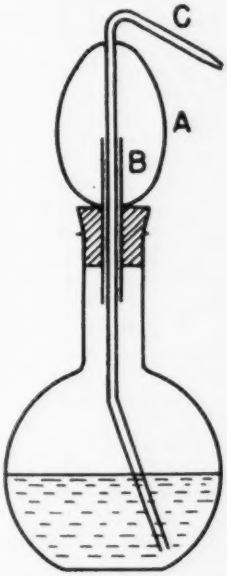
An Electrical Resistivity Apparatus for Testing Well Waters. J. F. POLAND AND R. B. MORRISON. Trans. Geophys. Union. *Part* 1: 35 ('40). Apparatus consists of measuring unit operating on 120- or 240-volt 60-cycle a.c. or from 6-volt storage battery, and cable-unit with attached electrode cell. Electrode cell was lowered into wells and resistivity measurements made continuously or at desired depth. Resistivity fairly dependable as index of chloride content, especially at concns. above 1,000 p.p.m.—*C. A.*

Nessler Tube Support. E. C. HOUSTON. Chemist Analyst. **29:** 66 (Aug. '40). Most of Nessler tube supports on market built to hold 12 tubes and require considerable desk space. For some determinations, such as estimation of titanium by colorimetric method, only 2 tubes required and small support is convenient. One described here may be constructed easily and at small expense. Support is made from block of well-seasoned wood, approx. 3″ x 4″ x 6″. 2 holes, having diam. somewhat larger than that of tubes and large enough to provide for possible shrinkage of wood, are drilled into end of block to depth of



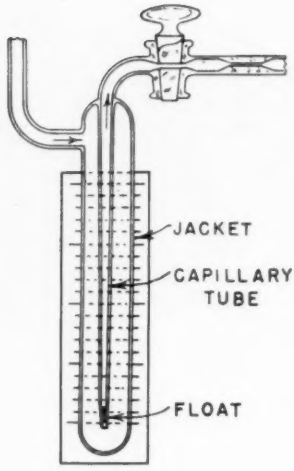
about 3″. Another drill bit, with diam. slightly smaller than that of tubes, then selected and holes are continued for additional ½″. Saw cut is made at right angles to 4″ face, at such position as to intersect holes of smaller diam. and extending about ½″ beyond holes. Wedge of material then removed from block by making second saw cut, starting on same face near bottom. Small white unglazed porcelain plate (mineralogical streak plate) makes good reflector and may be attached to sloping cut with molding or tacks.—*Ed.*

Dripless "Remote Control" Washing Bottle. RALPH E. DUNBAR. Chemist Analyst. **29:** 69 (Aug. '40). Dripless washing bottle, capable of being operated with one hand, can be constructed easily, as illustrated. Rubber pressure bulb, *A*, with valves removed, attached to short length of glass tubing, *B*. *B* slips loosely over glass delivery tube, *C*, and admits air to flask when bulb is squeezed. Tight connection at both ends of pressure bulb essential. When pressure applied, air enters flask forcing water from delivery tube in usual fashion. When pressure released, air again drawn back through delivery tube removing water present and, thus, preventing troublesome dripping. Use of



mouth not required in operating bottle and one hand left free for other work. Similar washing bottle may be constructed by attaching "nipples pipette" rubber bulb to mouth-piece of ordinary washing bottle. Operation will be facilitated in latter case by bending glass tubing in such a way that bulb lies along neck of flask.—*Ed.*

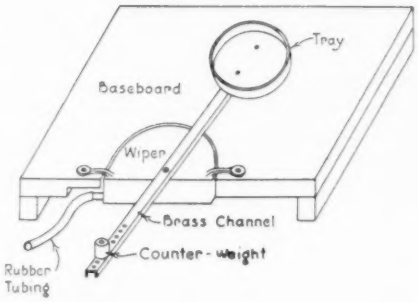
A Capillary Flowmeter. HUBERT N. ALYEA. Ind. Eng. Chem.—Anal. Ed. **12:** 686 (Nov. '40). Instrument designed for measuring rate of flow of liquid. Registers, continuously, flow of a few



ml. per hr. Jacket, 15 mm. in diam., supports capillary tube 20 cm. long, with bore of 0.1 mm. at lower end and 2 mm. at upper. Float in inner tube tapered slightly and made of colored glass to facilitate visibility. Flow of liquid is indicated in fig. Requires constant-pressure head at inlet and restriction at outlet. As with commercial rotameters, in which same principle is applied for large rates of flow, height of plunger indicates rate. Accuracy of meter may be judged from data on rate of flow of methanol through a capillary used by author. With float 1 cm. above lower end of capillary, flow was 1.7 ml. per hr.; 6 cm. above lower end, 4.8 ml. per hr. Design renders meter insensitive to momentary fluctuations in room temp.—*Ed.*

Simply Constructed Color Comparator. RICHARD H. WILHELM. Ind. Eng. Chem. —Anal. Ed. **13:** 123 (Feb. '41). Simple comparator which depends on fact that curved bars of certain resins transmit light through curved surfaces without appreciable loss described. Two straight cylindrical rods of resin (Plexiglas or any acrylate or methacrylate resin with similar optical properties) softened by heating to about 110°C., and one end of each bent through approx. 30° angle. Half of remaining straight portion of od removed by milling, leaving flat surfaces, which were cemented together with strip of reflecting aluminum foil between, using as adhesive some of resin dissolved in equal parts of chloroform and carbon tetrachloride. To shut out stray light, lateral surfaces coated with opaque lacquer made from aluminum powder dispersed in above adhesive solution. Flat ends ground fine and polished. Small convex lens in brass tube fitted to eyepiece and focused on resin surface. Other angles than 60° between light sources not tried. Device enables observer to view sample and standard tubes simultaneously for comparison.—*Selma Gottlieb.*

An Inexpensive Agitator. CHARLES E. COUCHMAN. Chemist Analyst. **29:** 93 (Nov. '40). Apparatus for producing continuous reversible motion sometimes useful in lab. Such devices costly and outlay for them considered unjustified if apparatus is used only occasionally. In many instance, application of vacuum type windshield wiper will serve purpose successfully. Construction of small lab. agitator shown in accompanying fig. is particular example of one application. After mounting wiper on base board, wiping arm is replaced by piece of brass channel. On one end of channel is fastened tray large enough to accomodate a 250-ml. flask. Adjustable counterweight is placed on opposite end. For operation, unit is connected to ordinary water suction pump by means of rubber tubing. Variable speeds of agitator controlled by amount of water flowing through pump. Lab. workers may find unit adaptable to variety of other purposes as well.—*Ed.*



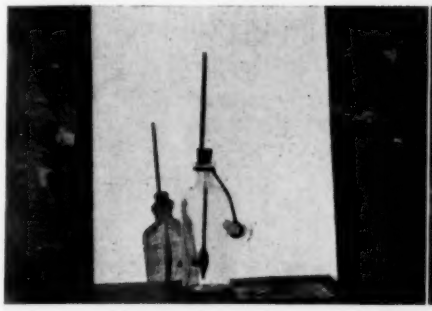


FIG. 1. Dissolved Oxygen Sample Bottle

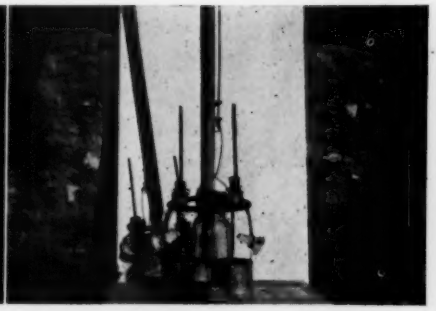


FIG. 2. Shallow Depths Sampler; showing assembly

Mechanical Aids to Stream Surveys. C. T. CARNAHAN. Pub. Health. Repts. **56**: 815 (Apr. 18, '41). Author describes and illustrates numerous devices used by U.S.P.H.S. on Ohio River and other stream surveys in accumulating lab. data. Evaluation of stream conditions

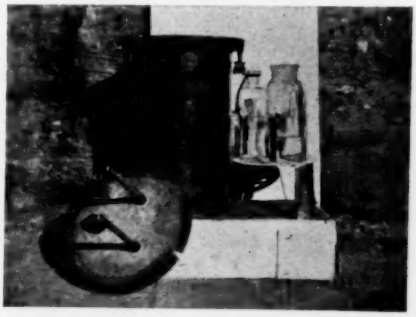


FIG. 3. Sampling Can; showing equipment included

depends largely upon analysis of many samples systematically collected. Usually analyses are physical, chemical, biological and bacterial. *Water Sampling Devices*: Single sample for dissolved oxygen (D.O.) test is taken in a collection bottle containing a 2-holed stopper fitted with 2 tubes, one extending to bottom, other a short distance above for air venting (Fig. 1). Device for collecting multiple samples from shallow depths consists of central pole with bottle holder at bottom for one bacterial and 2 D.O. bottles (Fig. 2). Sliding wire rod with end clip, attached to pole, permits slight raising of stopper in bacterial bottle and restoppering after filling. D.O. bottles equipped as previously described. Larger, deeper streams require a modified device (Fig. 3) for multiple sample collection, consisting of suitably weighted metal can with tight fitting cover, inside rack for bottles, water inlet tubes for D.O. bottles, arrangement for inserting sterilized water inlet tube to bacterial bottle, and air outlet from can, capable of being valved to permit collection at given depths, thus displacing D.O. bottle contents several times before can fills to air vent level. Latter and bottle holder are adjusted to stop filling when water reaches shoulder of bacterial bottle and just completely fills D.O. bottles, preventing contamination of former by overflow of latter. Device could be improved either by addition of vane or rudder to prevent can twisting in current and fouling air valve release line, or suspending sampler by spring release arrangement to permit

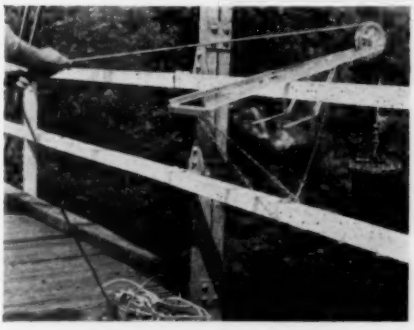


FIG. 4. Bridge Hoist in Operation; showing assembled sampling can

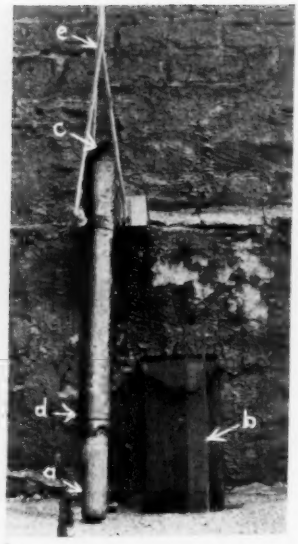


FIG. 5. Bottom Sampler; showing parts: *a*. steel tube; *b*. glass cylinder for sample; *c*. free acting flap valve; *d*. lead casing for added weight; and *e*. lifting rope

FIG. 6. Purdy Mud Scoop

opening air valve by jerk on lift line alone. When sampling from high bridges, portable hoist (Fig. 4), consisting of A-frame attachable to railing and secured by light chains fore and aft, used. Sampler rope passes through pulley on overhanging end. *Mud Sampling Devices*: Bottom sediment samples are valuable in stream surveys. Ordinary core drilling apparatus of reasonably large diameters are impractical in such sampling. Nearest approach consists of a heavily weighted and sharpened tube (Fig. 5) dropped to stream bottom

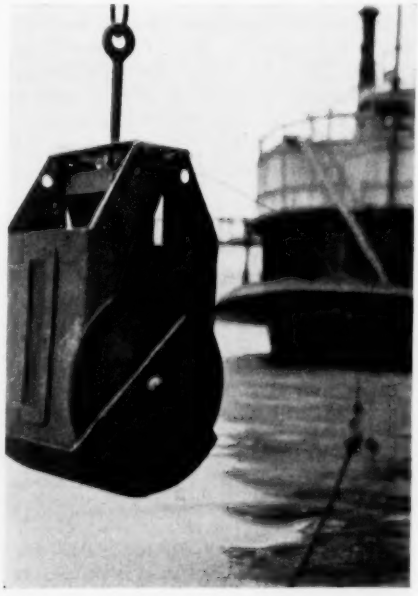


FIG. 7. Bottom Sediment Sampler; showing bucket in closed position

and which may be driven further by weighted hammer operating along lifting cable. Open ended glass tube inserted, rests on ledge above cutting edge and receives core sample. After raising sampler, upper end of glass tube is stoppered, sampler inverted and tube with core pushed out with ramrod. Bottom deposits may be dredged up by weighted scoops. Purdy Scoop (Fig. 6) with weighted handle falls to horizontal at stream bottom permitting cutting edges to dredge up sample on hauling to boat or shore. Richardson dredge is

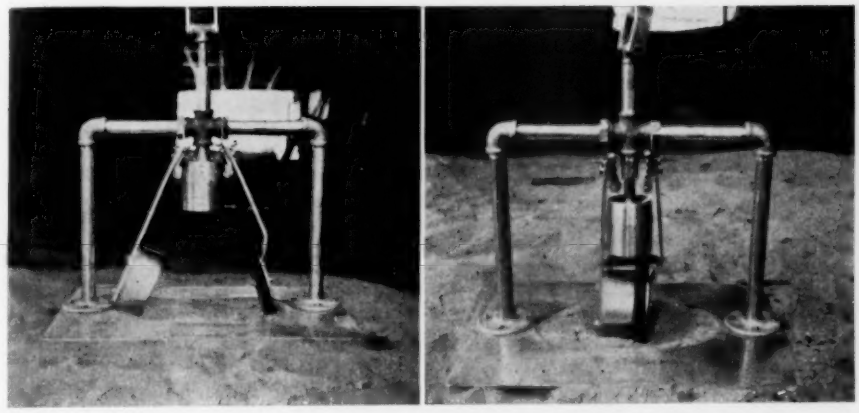


FIG. 8. Surface Sampler for Bottom Deposits; showing opened and closed positions

essentially a clam shell bucket constructed to heavy gage sheet metal, closed on submergence by strong spring. Operation difficult in stiff or heavy material. Author developed improved modification (Fig. 7) of clam shell bucket dredge by construction of heavy boiler plate upper box section for dredged material. Sides equipped with windows of thick cellulose acetate through which catch is observed for stratification. Operation possible in clays as well as soft sludge and provides ample sample. Gravel dredges with difficulty unless mixed with clay, sand or silt. Since empty bucket weighs 100 lb., derrick and winch necessary for handling. For examining surface layer bottom deposits author developed light wt. sampler from brass pipe fittings and structural shapes (Fig. 8). When suspended freely at end of lifting cable with cup and scraper in open position, it remains so until base plate rests on bottom. Further cable slacking permits free-moving, slightly conical, heavy bronze wedge to drop by own wt., while cup and scraper are forced together by steel springs. This action scrapes portion from upper ½″ to 1″ layer of deposit, forcing it into cup. Upon return, concave depression in top of wedge engages roller lugs on operating arms, holding jaws tightly closed against sponge rubber gasket. Apparatus useful in rapid survey of bottom material, working well in clay, sand, small gravel, silt and combinations. Samples equal about 100–150 ml. *Laboratory Equipment*: Upward flow washer (Fig. 9) has been devised to separate sand or grit from portion of mud sample for measuring. Lower end of 2½″ diam. glass tube contains home-made uniformity diffusing apparatus. Rate flow-meter gages

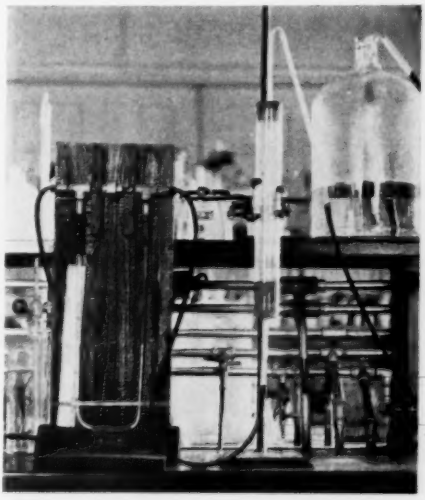


FIG. 9. Upward Flow Grit Washer

wash rate. Known portion of sample is placed above diffuser, upper end of tube stoppered with outlet drain, and predetermined rate of wash water flow allowed to proceed until effluent clear. Residual wash water is bypassed at bottom then heavy materials removed

for measurement. Biochemical oxygen demand test of bottom sediment by dilution method necessitates keeping mud portion of sample in test bottle continually suspended to prevent anaerobic conditions incident to otherwise undisturbed settlings. Agitation is accomplished by $\frac{3}{4}$" plywood box (Fig. 10), containing 56 bottles in $\frac{1}{4}$" plywood "egg-crate" partitions, rotated on $\frac{1}{3}$ h.p. motor-driven shaft at 1 r.p.m., completely installed in a 20°C. incubator. *Mobile Laboratory Units*: Six auto trailer laboratory units bring procedure to the stream and greatly increase operating area (see Jour. A.W.W.A., **33:**

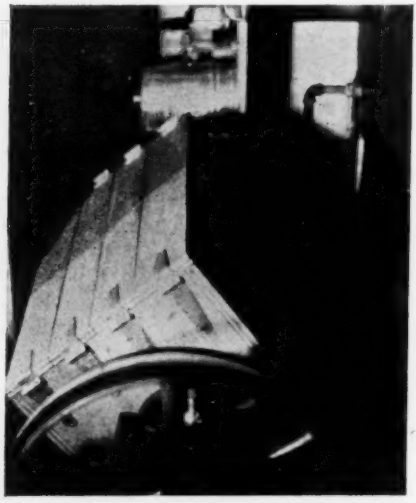


FIG. 10. Plywood Agitation Box in Operation

636 ('41). Reconditioned double decked quarter boat constructed on steel barge serves as a floating completely-equipped laboratory with power, heat, and living quarters. Samples brought by motor boats and automobiles from a 75-mile radius. Range of laboratory work done comparable to that of fixed land unit. *Other Apparatus and Equipment*: Standard and specialized laboratory apparatus, modern transportation and communication facilities, calculators, comptometers, typewriters, all contribute to total efficiency. *Need of Trained and Skilled Personnel*: Many and varied tools are of little value unless intelligently operated by adequate, competently trained and reliable personnel interested in and skilled at their work. Deft, sure movements of a skilled worker may mislead uninitiated observer to depreciate actual value of time and effort required to educate and train that worker. "Streamlining" and "mechanizing" lab. does not eliminate need for high grade personnel described. —*Ralph E. Noble.*

Measuring Average Particle Diameter of Powders. ERNEST L. GOODEN AND CHARLES M. SMITH. Ind. Eng. Chem.—Anal. Ed. **12:** 479 (Aug. '40). Self-calculating apparatus for direct detn. of av. particle diam. of powders depends on fact that current of air flows more readily through bed of coarse powder than through fine. Apparatus is so arranged that particle size may be read directly from scale mounted behind manometer measuring air pressure. Results are reproducible within 5% over 1 to 50 micron range. Time for detn. varies from few min. to an hr., depending on fineness of sample and difficulty of compacting.—*Selma Gottlieb.*

Method of Precise Determination of the Granulometric Composition of Sand. F. H. KHAL'FIN. Vodos. Sanit. Tek. (U.S.S.R.) **15:** 2-3: 89 ('40). Glass tube 600-650 mm. high and 25-30 mm. inside diam. is stoppered at both ends. Copper tube, 10-12 mm. in diam. passes through lower stopper and is connected to water faucet and manometer, upper soldered end having 6-8 side perforations 1.5-2 mm. in diam. Funnel-shaped tube is passed through upper stopper, outer end of tube leading to can with fine sieve bottom. Dried sand (200 grams) is placed in cylinder; water is carefully admitted just to reach top; and then valve is opened a little more to carry over finest sand. Pressure is increased in small steps, manometer being used for last fractions (when it becomes difficult to judge pressure otherwise). Volume of 0.1 gram of sand is taken as 36.4 cu.mm., and diam. is calculated from no. of grains. Table of sand grain diams. from 5 to 3,000/0.1 gram given. Proposed method more tedious than sieve analysis but gives more precise picture of sand composition.—*C. A.*

Friction as an Indicator in Titration. ROBERT E. D. CLARK. J. Soc. Chem. Ind. **59:** 216 ('40). Almost every one has noticed slippery feeling of basic solutions. Now shown that it is possible to utilize friction exerted by solution for determining end-point of acid-base titration or for determination of hardness of water with soap solution. Apparatus consists of synchronous motor connected with rotating wheel which is partly immersed in solution. Over wheel a silk thread is passed and there is a pointer. Distinct movement of pointer is noticed when end-point is passed. Fairly satisfactory results can be obtained.—*C. A.*

A Method for Obtaining Continuous Records of Dissolved Oxygen in Lake Waters. WINSTON M. MANNING. Ecology. **21:** 509 ('40). Dropping-mercury electrode which can be immersed in lake or stream and connected with recorder on shore to give continuous record of changes in concentration of dissolved oxygen described. Temp. is recorded simultaneously for correcting oxygen curves.—*C. A.*

BACTERIOLOGY

Wilson Method for the Bacteriological Examination of Water. R. FERRAMOLA. Am. J. Pub. Health. **30:** 1083 ('40). Method consists of primary incubation of water sample in MacConkey broth at 37°C. Subsequent positives are subcultured into MacConkey broth to be incubated at 44°C. (under carefully controlled conditions), and into citrate medium incubated at 37°C. for further 24 hr. Author, having had experience with method in England, examined about 10,000 samples of water in Argentina and carried out controls of main steps of Wilson method by plating out positive tubes and typing colonies according to Ministry of Health classification. Presumptive coliform count in MacConkey broth at 37°C. gave 97% correct results in 24 hr. and 86% after 48 hr. incubation. Majority of false presumptives encountered in samples that had been 2 days in transit to lab. From 430 presumptive positive tubes, 51 (12%) false positives were obtained, 45 of these gave growth on plating but organisms failed to ferment lactose (but majority would probably have fermented dextrose); remaining 6 organisms gave no growth on plating (the original fermentation probably being due to *Cl. perfringens*). Accuracy of incubation at 44°C. as measure of fecal coliform content was very decisive, 95% of tubes fermenting MacConkey broth at 44°C. did so in first 24 hr., and 97% of these proved to be fecal coliform organisms. To demonstrate specificity of 44°C. MacConkey test for fecal coliform organisms in sewage and feces, several hundred coliform organisms were isolated from sewage and animal excreta. All but 6 of 963 *Esch. coli* I strains produced gas in MacConkey broth at 44°C.; 4 *Esch. coli* II strains were obtained, 2 were positive at 44°C. and 2 negative (fecal signif. of organism in some doubt). 10 other coliform strains obtained, all failed to give gas in MacConkey at 44°C. Confirmation of growth in citrate as indicative of I.A.C. [intermediate *aerogenes* and *cloacae*] organisms was 92% correct in 24-hr. presumptives and 61% in 48 hr. positive tubes. Exam. of colonies from false positive citrate tubes showed them to consist of non-lactose fermenting, gram-negative bacilli (presumably fermenters of dextrose). Suggested that these organisms are I.A.C. in type but have temporarily lost power to ferment lactose in 24 hr. Concluded that although specificity of citrate test for I.A.C. organisms is not so high as 44°C. MacConkey test for fecal coliform organisms it is, nevertheless, of reasonably high order. Finally, comparison made between American Standard and Wilson methods on 499 samples with regard to coliform count. Results remarkably similar by two methods. From total of 3,245 tubes inoculated, discrepant results obtained in only 39 cases. Interesting to note that very small proportion of fermented lactose broth

tubes in American Standard method confirmed as coliform organisms by plating, namely 356 from 1,238 positive tubes (or 29%). Wilson method, on other hand, produced but 423 positive tubes of which 373 (88%) were confirmed by plating. Thus for almost ¼ labor and material of subculture, actually more tubes confirmed as coliform organisms by Wilson method than by American Standard method. Author concludes that, in view of simplicity and specificity of Wilson method, and fact that it gives a differential as well as confirmed coliform count in same time as that required by American Standard method gives coliform count alone, method warrants further trials on extensive scale.—*B.H.*

The Bacteriological Examination of Water Supplies. CLARA RAVEN, D. PEDEN AND H. D. WRIGHT. J. Pathol. and Bact. **50:** 287 ('40); Bul. Hyg. **15:** 569 (Sept. '40). Results from 2 yr. work in analysis of Liverpool water supply discussed, emphasizing 3 items: (1) 94.5% of *Esch. coli* isolated obtained from 24-hr. presumptive tubes, i.e., additional incubation, 24–48 hr., detected only 5.5%. This not true for group—only for *Esch. coli*. (2) From comparison of MacConkey's medium in presumptive test with incubation at 37° and at 44°C. for *Esch. coli* isolation, there is slight but inconclusive evidence favoring lower temp. As confirmatory medium, MacConkey's at 44°C. was very effective for *Esch. coli*. Temps. above 44°C. were apparently not considered suitable. (3) Growth in citrate not considered specific as differential test.—*P.H.E.A.*

Uses of a Lauryl Sulfate Tryptose Broth for the Detection of Coliform Organisms. W. L. MALLMANN AND C. W. DARBY. Am. J. Pub. Health. **31:** 127 (Feb. '41). Study made in effort to determine improved method of coliform detection, deemed necessary because of passage, through purif. plants, of organisms that appear to have caused intestinal upsets even though water being produced met all bact. requirements of safe supply. Outbreaks often accompanied by presence of "slow lactose fermenters." Shown previously that tryptose caused these bacteria to produce more gas from lactose in less time than standard lactose broth. Tests made with various wetting agents to det. if all surface tension depressants showed selective action for coliform group. Of (1) Aerosol-M.A. (2) Naconol N.R.S.F., (3) Duponol W. A. Paste, (4) Santomerse #1 and (5) Igepon T, (1) and (5) have no selective action and (2) and (3) were equal in selectivity both as to organisms and degree of action. Agents showed some toxicity at 1:100 concentration; none at 1:10,000. Ideal medium then appeared to be tryptose lactose broth plus 1:10,000 dilutions of (3) (sodium lauryl sulfate) or (2). Co-operative tests made in 6 water plants. Tap water tested in each lab.; comparison made in 3 media in parallel lactose broth (L.B.), tryptose broth (T.B.) and lauryl sulfate tryptose broth (L.S.T.B.). Of 1,584 tubes tested, 238 showed gas in L.B., of which only 4 tubes confirmed in B.G.B., 68 showed gas in L.S.T.B., all confirming. Similar results reported for a yr. test at Highland Park, Mich., 107 L.B. showing gas out of 3,510 tested, none confirming; and with L.S.T.B. only 2 tubes gave gas, neither confirming. In polluted raw water tests on parallel primary planting, 454 L.B. tubes showed gas and 422 confirmed in B.G.B. Of 470 forming gas in T.B., 429 confirmed; and in L.S.T.B. 469 gave gas and 426 confirmed—43 failing to confirm as against 32 for L.B. and 41 for T.B. L.S.T.B. appears to fail in holding back non-coliform organisms. Study of this then made by plating routine, T.B. and L.S.T.B. tubes showing gas and failing to confirm, into B.G.B. or onto E.M.B. Observations demonstrated that confirmatory media apparently either caused organisms to lose ability to ferment lactose or inhibit their growth; also demonstrated T.B. allows organisms to grow and form gas that otherwise failed in L.B. In further tests, observed that in many instances atypical colonies on E.M.B. from L.B. failed to produce gas in L.B. on transfer, but on transfer to T.B. produced gas in considerable quantities; also when nega-

tive L.B. tubes were transferred to T.B., gas production followed. Appears E.M.B. and B.G.B. cannot be used for confirmation if desirable to obtain confirmation on all coliform organisms in L.B. In tabulation of gas and confirmed indices, poor agreement shown between gas and confirmed index for L.B., good agreement for T.B. (confirmation through E.M.B. or B.G.B.). Data indicates gas production in L.S.T.B. could serve not only as presumptive test but also as a confirmative medium for routine testing. Confirmation always obtained if gas present. Suggestion made that media should be checked further in plants.—*Martin E. Flentje.*

A Study of Methods for the Detection of the Presence of Coliform Organisms in Water. *Committee Report.* N. J. HOWARD, A. G. LOCHHEAD AND M. H. MCCRADY. Can. Pub. Health J. **32:** 29 (Jan. '41). Results obtained in study of brilliant green bile as confirmatory medium carried out in 5 Canadian labs. are presented and discussed. Procedure was as follows: (1) 5 portions of 1 ml. and 5 of 10 ml. were planted in standard lactose broth and incubated at 37°C. for 48 hr. (2) If, and when, gas in any amount appeared, confirmation was made according to standard method and, in addition, loopful was transferred to brilliant green bile (2%). (3) Latter was incubated at 37°C. for 48 hr., and subjected to standard confirmatory tests as soon as gas appeared. Complete confirmation of brilliant green transfers yielded more isolations of coliform organisms than did direct complete confirmation of lactose broth presumptives. Unconfirmed brilliant green bile positives, however, exceeded, by 11%, no. of presumptives shown by (2) and (3) to contain coliform organisms. Concluded that rapid confirmatory test of simply transferring to brilliant green bile is quite as satisfactory as more involved and time-consuming "completed test." Too many coliform organisms will be indicated rather than too few and any error is therefore on safe side. If isolation and identification is desirable in special cases, "completed test" of brilliant green bile gas positives yields results that are as dependable as those secured by isolation directly from primary lactose broth presumptives, often with considerable economy in labor and materials.—*R. E. Thompson.*

Observations on the Differentiation of Bact. Coli and Bact. Aerogenes on Levine's Simplified Eosin Methylene Blue Agar as Applied to the Bacteriology of Water in Bengal. SUKUMAR NEOGI. Indian Med. Gazette. (India) **75:** 519 (Sept. '40). Author briefly reviews literature dealing with differentiation of coliform organisms and presents results of study of Levine's E.M.B. In exam. of 40 samples from various sources in Bengal, 966 colonies from E.M.B. plates were selected for differentiation. On colonial appearance, 642 were classed as *Esch. coli* and 324 as *Aer. aerogenes.* Indol production, methyl red reaction, Voges-Proskauer and growth in Koser's citrate tests were applied. On basis of these tests, 642 strains, called *Esch. coli,* on E.M.B. proved to be 75.2% *Esch. coli,* 21.6% intermediates, and 3.2% *Aer. aerogenes.* Of 324 called *Aer. aerogenes,* 71.3% were *Aer. aerogenes,* 21.6% intermediates, and 7.2% were *Esch. coli.* Author concludes that differentiation on E.M.B. under Bengal conditions might be adopted for "partially confirmed tests," but "should not be considered as strictly reliable."—*P.H.E.A.*

The Nature of the Lactase of *Bacterium coli mutabile* as Determined by Studies of Mixed Populations. I. D. MICHELSON. (*Published in abstract only.*) J. Bact. **41:** 29 (Jan. '41). Expts. made to determine constitutive or adaptive nature of lactase of *Bacterium coli mutabile.* Broth tubes were inoculated with organism (10^{-2} final conc.) and its lactose variant (10^{-5} to 10^{-8}, respectively). These mixed cultures were transplanted daily for 2 mo. Lactose-fermentation rates were determined for above concs. of parent strain, its lactose variant, and for mixtures. Determined, also, at weekly intervals for mixed cultures. Plating to Endo's medium correlated presence and no. of lactose-fermenting organisms with rate of fermentation.

As control, *Bacterium coli commune* substituted for lactose variant. *Commune* established itself readily in such mixed cultures, as evidenced by marked decrease in lactose-fermentation rate and by presence of lactose-fermenting organisms on Endo's plates. Lactose variant gradually disappeared from its mixtures, beginning in those tubes containing lowest initial conc. of variant. Very small nos. of lactose-fermenting organisms can be detected by changes in basic rate of lactose fermentation. Metabolic activities of *Bacterium coli commune* and lactose variant of *Bacterium coli mutabile* differ. Delayed fermentation of lactose by latter may depend upon time required for establishment of favorable cultural conditions or for sufficient cells to acquire lactase enabling them to grow in presence of parent cells. Adaptive nature of lactase suggested.—*Ralph E. Noble.*

Coliform Bacteria and Streptococci in Swimming Pool Water. RALPH L. FRANCE AND JAMES E. FULLER. Am. J. Pub. Health. **30:** 1059 (Sept. '40). Object of article to compare bact. results of streptococcus and coliform tests on samples taken from a college swimming pool. Coliform test accepted as more accurate measure of intestinal pollution. Methods used in making test are given. Procedure for demonstrating test is that recommended in *Standard Methods.* Daily schedule of sampling of pool gives time and condition of pool when samples were collected. 3 tables give comparative results of tests. In each test, greater no. of streptococci positive tubes were produced in various dilutions than were produced in coliform test.—*P.H.E.A.*

Studies on a Series of Coliform "Citrate-Mutants" With Particular Reference to Their Stability. LELAND W. PARR. (*Published in abstract only.*) J. Bact. **41:** 29 (Jan. '41). A "mutant" should show stability in character under consideration. 22 strains of coliform organisms derived from 2 original parent cultures, H.23 and T.16, were studied with respect to constancy of action on Simmon's citrated agar. Numerous control cultures of various coliform types used, and for each of 22 strains, many subcultures and multiple pickings from platings to broth and citrate were made. Duplicate runs were made for 12, and triplicate runs for several others. 1 strain was tested 6 times, another 10. Runs differed in length from that on H.23–12, involving 79 serial subcultures and picking of over 1,000 colonies, to the min. routine, in which strain was tested in 5 serial subcultures with a study of 200 colonies. Certain strains found entirely stable with respect to citrate. One proved entirely stable with exception of a single colony in more than 1,000. Other strains not perfectly stable. Thus, T.16–7 yielded, in practically all subcultures, mixtures of citrate-pos. and citrate-neg. colonies, although when originally derived it bred true as a citrate-pos. for considerable number of "generations." Believed different strains exhibit different grades of stability, and that this factor should be kept in mind in all bacteriological work.—*Ralph E. Noble.*

Variation in Gas Production by *Aerobacter cloacae*. NEWELL R. ZIEGLER AND LAVEGA R. SHELTON, JR. (*Published in abstract only.*) J. Bact. **41:** 28 (Jan. '41). Variants of a recently isolated single-cell strain of *Aerobacter cloacae* were obtained by cultivation on nutrient-agar plates containing increasing amount of molar sodium monochloracetate for different time intervals. Amount of gas produced by colonies of single-cell stock culture and variant strains, during fermentation of 1% *d*-glucose in nutrient broth, was determined by daily measurements of length of gas bubble formed in a Durham fermentation tube. Measurements made until max. reached. Data obtained have been analyzed statistically to determine whether differences observed in gas production are significant. Coef. of variation of individual measurements of max. gas formation from mean was used as quant. measure of stability. Comparison of coefs. shows single-cell stock culture to have lowest value and greatest stability. Cultivation of organism on agar containing different concentrations

of sodium monochloracetate and grown for different periods, decreased amount of gas formed as well as biochem. stability. Some indication that increased time of contact with chemical is greater factor in producing instability than increase in conc.—*Ralph E. Noble.*

Clear Liquid Mediums for the "Aerobic" Cultivation of Anaerobes. J. H. BREWER. J. Am. Med. Assn. **115:** 598 ('40). Author describes clear fluid medium in which conditions remained anaerobic on ordinary "aerobic" incubation without any paraffin seal, so that methylene blue in 1/500,000 conc. was decolorized except for surface layer of 5 mm. (24 hr.), 8 mm. (48 hr.), 10 mm. (72 hr.), 12 mm. (1 wk.) and 25 mm. (1 mo.). Growth was obtained from small inocula of spores of *Cl. Oedematiens, Cl. tetani, Cl. septique, Cl. botulinum, Cl. perfringens, Cl. sporogenes* and from several strains of anaerobic streptococci. Medium consists of pork infusion solids (1%), peptone (1%), sodium chloride (0.5%), sodium thioglycollate (0.1%), and agar (0.05%). Dextrose (1%) may be added. Medium is sterilized in autoclave. Has been prepared in dehydrated form by Baltimore Biol. Lab. and satisfactory media were made from powder after several months of storage.—*B. H.*

A Simple Modification of Wilson and Blair's Medium for the Isolation of Typhoid and Paratypoid Bacilli. (*Brilliant Green, Bismuth-Ammonium Citrate and Sodium Sulfite Medium.*) SAGA TYAGARAJA. J. Hyg. (Br.) **40:** 414 ('40). Glucose, sodium phosphate and ferrous sulfate are eliminated from original formula and bismuth ammonium citrate solution is made without sodium hydroxide. New medium (B.B.S.) keeps several weeks and deterioration is readily detected and rectified. Inhibitory action toward *Aer. aerogenes* is greatly improved. Typhoid and *Salmonella* grow readily.—*C.A.*

Note on the "Most Probable Number" Index as Used in Bacteriology. J. M. DALLAVALLE. Pub. Health. Rpts. **56:** 229 (Feb. 7, '41). Since accuracy of most probable number (M.P.N.) for 3 different dilutions (dils.) depends upon no. of tubes used, little statistical reliability can be placed upon values obtained unless no. of tubes is more than 20. Nor is probability very great that given combination of pos. tubes will occur frequently even when repeated infinite no. of times on same sample. All M.P.N.'s cannot be equally reliable. Use of 3 dils. affords only: (1) estimate of bacterial no. present in sample of unknown content; and (2) allocation of statistical discrete value regardless of pos. and neg. tubes and "skips." When no. of tubes is 40 or more, accuracy obtained is about same as with single dil. Thus, 3 dils. adds little to accuracy of final result if M.P.N. can be estimated roughly. Total tubes in 3 dils. applied to one dil., in all probability, would increase accuracy. ★[But, what single dil. shall be selected for a sample of uncertain coliform content?]★—*Ralph E. Noble.*

The Significance of the Occurrence of Bacteriophage for Dysentery Bacilli in Water Supplies. A. J. RHODES AND M. LUDLAM. J. Hyg. **39:** 658 ('39). Methods used for detection of phage in water described by Morison. Only on one occasion was phage detected in unenriched sample of water. This was lytic to both *Shigella sonnei* and *Shigella dysenteriae.* Phage frequently detected, however, in water samples when enriched with dysentery organisms or *Esch. coli.* Well-marked lysis produced with homologous organism, but, in addition, there was lysis of many other dysentery test cultures, *Esch. coli,* and, on one occasion, in cultures of *B. typhosum* and 2 *Salmonella* organisms. Phage readily detected in samples of loch water, but lytic principle had been removed from some samples, following sand filtration. Samples of water tested came from sources free from possibility of human contamination, but open to infection from grazing animals and gulls. 16 strains of *Esch. coli* isolated from gull feces and 2 were shown to carry phage which lysed dysentery bacilli. Findings indicate that isolation of phage for dysentery bacilli from water sample not

specific test of contamination by these pathogenic organisms. Presence of phage no more than evidence of animal (including human) contamination and ". . . is of little value in epidemiological investigation of outbreaks of bacillary dysentery."—*B. H.*

Survival of Microörganisms in Sodium Chloride Solutions and in Distilled Water. F. W. TANNER AND C. W. HOUSTON. Zentr. Bakt., Parasitenk., II Abt. **102:** 354 ('40). Distilled water as good as sodium chloride solution for storing most bacteria. More favorable for *Esch. coli* and *Eberthella typhosa*. Ave. survival time in water 3–12 days and in saline, 2–4 days. *Salmonella aertrycke* and *Serratia marcescens* may live as long as 40 days in water. Yeasts favored by sodium chloride concentration of 1.0–1.2%. Higher the no. of organisms in the suspension, longer the survival, perhaps because of development of resistant forms.—*C. A.*

The Influence of De-Chlorination on the Bacteriologic Investigation of Water. A. YA. ZVENIGORODSKAYA AND G. A. MANUILOVA. Vodos. Sanit. Tekh. (U.S.S.R.) **15:** 7: 37 ('40). To eliminate influence of Cl on bacteria prior to analysis, U. S. practice of $Na_2S_2O_3$ addn. found satisfactory. 84 expts. conducted. Importance of immediate de-chlorination definitely established.—*C. A.*

CHEMISTRY

[**Nomenclature in Base Exchange Processes.**] *Editorial.* Jour. Chem. Educ. **17:** 504 (Nov. '40). Recent article on "Base Exchange Resins" in water softening uses terms "acid" and "base" inconsistently. Consistent modern usage classifies calcium and other metal ions as acids (not bases), hence logically substituted by acid hydrogen. All negative ions (e.g., sulfate) are bases (not "acid ions") hence logically substituted by basic hydroxyl ion.—*Selma Gottlieb.*

Determination of Biochemical Oxygen Demand and Dissolved Oxygen of River Mud Suspensions. C. C. RUCHHOFT AND W. ALLAN MOORE. Ind. Eng. Chem.—Anal. Ed. **12:** 711 (Dec. '40). So-called immediate or chem. oxygen demand of mud suspensions is not true measure of chem. demand, but is an apparent oxygen loss due to failure of analytical methods employed. Interference is apparently caused by reaction between reagents used for D.O. detn. and substances in mud. Interfering substances can be removed by centrifugation in completely filled glass-stoppered bottles or by flocculation with alum and ammonium hydroxide (10 ml. of 10% alum soln. followed by 1 to 2 ml. of conc. NH_4OH per 300 ml. sample). In detg. B.O.D. on river mud suspensions authors recommend (1) calculation of initial D.O.; (2) maintenance of solids in suspension during entire incubation period in specially constructed apparatus rotating about 1 r.p.m.; and (3) detn. of D.O. on rotated incubated sample after clarification by alum flocculation. Mud samples studied were septic and viscous, containing 38 to 68% solids, of which 6.07 to 10.1% were volatile matter.—*Selma Gottlieb.*

Determination of Biochemical Oxygen Demand. O. R. PLACAK AND C. C. RUCHHOFT. Ind. Eng. Chem.—Anal. Ed. **13:** 12 (Jan. '41). Rideal-Stewart and sodium azide modifications of Winkler method for dissolved oxygen both give reliable results for detn. of B.O.D. in river pollution studies. Most samples studied had B.O.D. values sufficiently low to eliminate dilution. Azide may be added directly after first acidification of sample or (Alsterberg modification) in combination with alkaline-iodide Winkler reagent. Former allows greater flexibility while latter has manipulative advantages for routine work. Preliminary treatment with acid and azide when sample is to be stored or transported before titration helps prevent oxidation and is preferable to complete Winkler treatment when titration is delayed. Alsterberg added 5 grams of sodium azide per liter of alkaline iodide.

Modified azide procedure: Add 0.7 ml. of concd. H_2SO_4 to sample as in Rideal-Stewart method, followed by 0.8 ml. of 2% aqueous sodium azide soln. Stopper, shake and allow to stand 10 min. Add 1 ml. of $MnSO_4$ (480 grams of $MnSO_4 \cdot 4H_2O$ per liter) and 3 ml. of alkaline-iodide soln. (500 grams of NaOH and 150 grams of KI per liter.) Shake for 20 sec., allow ppt. to settle and acidify with 2 ml. of concd. H_2SO_4. Titrate liberated iodine on volume of soln. equivalent to 200 ml. of original sample immediately with 0.025 N $Na_2S_2O_3$ using starch indicator.—*Selma Gottlieb.*

The Determination of Hydrogen Ion Concentration. ANON. Engineering. (Br.) **150:** 21, 64 (Jan. 10, 24, '41). Properties of solution, vaguely described by terms acid, neutral, or alkaline, can be expressed quantitavely by single term "hydrogen ion concentration." Quantity can be measured accurately only by determining potential developed between the solution and suitable electrode by virtue of electric charge of ions in solution. This electrical potential bears definite relation to pH of solution. Electrodes of various types can be used not only for ordinary solutions, but also for viscous liquids and pastes. Standard electrode, to which all others are referred, is hydrogen electrode. Most usual form consists of platinum plate, coated with platinum black, around which hydrogen gas is bubbled. Potential E_h, in volts, between hydrogen electrode and solution has following relation to pH of solution at temp. of t°C. $E_h = -0.0001984(273 + t)$pH. Other forms of electrodes, such as antimony and quinhydrone, widely used in industry, but type that is of principal interest is glass electrode which owes its action to fact that, when thin glass membrane separates two solutions, electrical potential, varying in relation to pH difference of solutions, is set up across membrane. The pH/e.m.f. relationship is practically linear up to pH 10. Where vigorous oxidizing or reducing conditions are met, glass electrode must be used. Other systems may be employed alternatively, according to pH range. To employ automatic control of pH values, electrode may be arranged for immersion in vessel through which solution under test passes in continuous flow. Varying e.m.f. from measuring electrodes is applied to potentiometer circuit, potentiometer being balanced automatically by device which also provides motive power for recording pen. Mechanism driven by elec. motor suitable for standard voltages. Switches incorporated in instrument and arranged automatically to operate valves, should recorded pH value vary beyond predetermined limits. Applications of instrument in metallurgical industries described.—*H. E. Babbitt.*

Preparation of Nessler's Reagent. A. P. VANSELOW. Ind. Eng. Chem.—Anal. Ed. **12:** 516 (Sept. '40). After preparing Nessler's reagent by various formulas and procedures, author concludes that reagent should have 10 moles of KOH for each equivalent of mercuric ion in soln., with 5% excess KI over requirement for hypothetical compd., K_2HgI_4. Should stand for several days before use to settle any precipitate. Involved methods of preparation unnecessary. Dissolve 45.5 grams of HgI_2 and 34.9 grams of KI in as little water as needed. Add 112 grams KOH (140 ml. of an almost satd. soln., sp.g. 1.538, 15°/4°) and dilute to 1 liter. Soln. is 0.2 N in Hg. For Nessler test, use 5 ml. reagent to 100 ml. of final vol. and compare color with standards 30 min. after mixing. Reagent prepared by this formula has been successfully used in author's lab. for several years.—*Selma Gottlieb.*

Experimental Study of the Stability of the Nessler Reaction and Its Application to the Photometric Determination of Nitrogen. LÉON GILLO. Bull. Soc. Chim. Biol. (Fr.) **21:** 1117 ('39). Final mixture should be at least 0.1 N in free sodium hydroxide to obtain max. color. Presence of various salts, especially sodium sulfate, promotes turbidity. Addition of 1% purified gum Senegal prevents turbidity, even in presence of high concns. of sodium sulfate. Method of purifying the gum is described. Extension curves are given for photometric

determinations with different light filters.—*C. A.*

The Conductometric Determination of Salts in Mineral Waters. K. SANDERA. Chem. Obzor (Czech.) **14:** 150 ('39). Total content of salts in mineral waters of Carlsbad, Poděbrady, Luhačovice, and Krondorf was calculated from specific electric conductivity, with aid of conversion factors. When these natural waters were diluted to give specific conductivity of approx. 50 to 250 $\times 10^{-5}$ ohm $^{-1}$ per cm. (350–1800 mg. of ash per liter), electric conductivity was almost directly proportional to mineral content of water. Storage of mineral waters or alteration of content of free carbon dioxide did not change conversion factor. With water containing mineral salts whose nature was unknown, conductivity multiplied by 7 gave approx. total content of dry salts in p.p.m. When sodium bicarbonate, potassium bicarbonate, calcium bicarbonate, sodium chloride, calcium sulfate, potassium sulfate, or sodium sulfate was present alone in a concentration between 600 and 1000 mg. per liter, conversion factors varied between 5.6 and 7.5, but they became constant between 6.7 and 7.2 for mixtures of the salts. With water of known source and composition, a conversion factor determined from previous analysis can be used. Total content of salts in a new spring computed by this method of calculation varied from 3,300 to 3,470 mg. per liter; gravimetric determinations on the evaporated residue gave 3,465–3,502 mg. per liter.—*W. P. R.*

The Inhibiting Action of Minute Amounts of Sodium Hexametaphosphate on the Precipitation of Calcium Carbonate From Ammoniacal Solutions. R. F. REITEMEIER AND T. F. BUEHRER. J. Phys. Chem. **44:** 535 ('40). Glassy sodium hexametaphosphate, at extremely low concentrations of the order of 1 p.p.m., prevents precipitation of calcium carbonate from solutions containing 200 p.p.m. calcium bicarbonate and 550 p.p.m. ammonia. Crystalline metaphosphate is relatively ineffective under similar conditions. At low calcium concentrations, pyrophosphates are as effective as metaphosphates; orthophosphates exhibit a slight ability to inhibit precipitation, but it is limited by precipitation of an orthophosphate of calcium. No other analagous inorganic salts, similar to phosphates, possess this property. It is highly specific of molecularly dehydrated phosphates only. Ultramicroscopic, photomicrographic and x-ray studies show that calcium carbonate does not remain stabilized in colloidal state owing to presence of metaphosphate. Large and grossly distorted crystals in place of typical rhombs of calcite form in presence of metaphosphate. Ratio of calcium to phosphorus is about 300 in presence of 0.6 p.p.m. metaphosphate. Mechanism of inhibition process is conceived to involve primarily restricted or deranged crystallization owing to adsorption of metaphosphate on crystal faces. Photomicrographs (44) of crystals are included. Theories of inhibiting action of metaphosphate are reviewed.—*C. A.*

The System Trisodium Phosphate—Sodium Carbonate—Water. KENNETH A. KOBE AND ALEXANDER LEIPPER. Ind. Eng. Chem. **32:** 198 (Feb. '40). Commercial trisodium phosphate (TSP) is approx. $Na_3PO_4 \cdot 1/7\ NaOH \cdot 12H_2O$, alkali content varying with composition of soln. from which TSP is crystallized. Solubility of salt of above composition in water and in sodium carbonate solns. was detd. at 6 temps. from 0 to 100°C. System TSP—Na_2CO_3—H_2O forms no double salt. TSP may be separated from soln. containing Na_2CO_3 by evaporating at 100°C. until crystals appear which are Na_2CO_3 unless TSP is in great excess. Further evaporation produces Na_2CO_3 alone to the invariant point where Na_2CO_3 and TSP crystallize together. Cooling from this point yields TSP alone due to retrograde solubility of Na_2CO_3. Lack of agreement in data of previous workers is laid to great influence of excess alkali or acid on solubility of TSP.—*Selma Gottlieb.*

Colorimetric Determination of Phosphate. S. R. DICKMAN AND R. H. BRAY. Ind. Eng. Chem.—Anal. Ed. **12:** 665

(Nov. '40). Using HCl instead of H_2SO_4 in colorimetric detn. of PO_4 by molybdate, interference by Cl is greatly decreased. Ferric iron from $FeCl_3$ up to 15 p.p.m. in final concn. does not affect color intensity. Higher amts. of Fe may be reduced to divalent form and color compensated for. Anions, such as SO_4, ClO_4 and NO_3 interfere if present in greater than certain concns. Reagents: I. 15.0 grams of c.p. ammonium molybdate in 300 ml. distilled water at 50°C. To cooled soln. add 350 ml. of 10.0 *N* HCl slowly with shaking. Cool to room temp. and dil. to 1,000 ml. with distd. water. Mix well and store in black glass-stoppered bottle. Should be replaced every 2 mo. II. Dissolve 10.0 grams of $SnCl_2 \cdot 2H_2O$ in 25 ml. of concd. HCl. Keep in black glass-stoppered bottle and replace every 2 mo. For use, add 1 ml. of this soln. to 332 ml. of dist. water. Shake well. Should be made up fresh after 8 hr. III. Dissolve 0.2194 gram of recryst. KH_2PO_4 in distd. water and make up to 1,000 ml. This soln. when dild. 1:10 gives soln. contg. 5.0 p.p.m. of phosphorus. For analysis, pipet aliquot of soln. into 25 x 200 mm. pyrex test tube graduated at 35 ml. If acid, add 5 drops of water soln. of quinaldine red and neutralize by adding NH_4OH drop by drop until soln. becomes pink. Add distd. water to exactly 35.0 ml. Add 10.0 ml. of reagent I, mix, then immediately pipet in 5.0 ml. of reagent II and mix thoroughly. Color intensity is constant between 4 and 20 min. Det. PO_4 in photo-electric colorimeter or visually, using standard PO_4 soln. similarly treated.—*Selma Gottlieb.*

Removal of Chlorides and Sulfates by Synthetic Resins. M. C. SCHWARTZ, W. R. EDWARDS, JR. AND GRACE BOUDREAUX. Ind. Eng. Chem. **32:** 1462 (Nov. '40). Resin prepared from m-phenylene-diamine, formaldehyde and hydrochloric acid was used to remove chlorides and sulfates from variety of aqueous solutions. Test solns. contained HCl, NaCl, HCl and NaCl, NaCl and NaOH and H_2SO_4, and were shaken mechanically in thermostat with resin. Drying resin at temp. from 31 to 130°C. had no appreciable effect on Cl removal. Effectiveness was markedly increased by rinsing with sodium carbonate soln. and water before drying at 92°, but this treatment increased solubility of resin and imparted color to effluent. Temp. between 30 and 45° had no effect on process. Reaction attains equilibrium slowly, 10 hr. being chosen as standard reaction time for work reported. Reduction of size to from 60–100 to 100–200 mesh increased efficiency but smaller than 20–40 is not practical for commercial units. Effectiveness of removal decreases with decreasing initial acidity of soln. (total Cl remaining constant or decreasing) though some NaCl is removed from neutral soln. Tests showed that whole HCl or H_2SO_4 molecule is removed. Resin removes H_2SO_4 considerably more effectively than HCl. Data indicate that salt formation involving amino groups of the resin is major factor in removal of acids from water by process studied, though adsorption is doubtless contributing factor. Bibliography of 48 titles.—*Selma Gottlieb.*

Preparation of Stable Sodium Thiosulfate Solutions. JAMES L. KASSNER AND ESTHER E. KASSNER. Ind. Eng. Chem., Anal. Ed. 12: 655 (Nov. '40). Small amts. of chloroform (about 3 drops per liter) prevent decomposition of $Na_2S_2O_3$ stored in rubber-stoppered bottles. Solns. of approx. 0.05 *N* or less should be stored in brown glass, rubber-stoppered bottles. Sterile $Na_2S_2O_3$ solns. of pH 6.2 or more maintain titer over long period of time.—*Selma Gottlieb.*

A Nitrosolignin Colorimetric Test for Sulfite Waste Liquor in Sea Water. IRWIN A. PEARL AND H. K. BENSON. Paper Trade Jour. **111:** 18: 35 ('40). Test consists essentially in adding to 50 ml. of water 1 ml. of freshly prepared 10% sodium nitrite and 1 ml. of 10% acetic acid, shaking, adding 2 ml. 2 *N* ammonium hydroxide, shaking again, and comparing either with standards prepared by adding known quantities of sulfite waste liquor to unpolluted sea water from same locality and treating in same way as sample, or with cobalt-platinum color standards prepared ac-

cording to method of Am. Pub. Health Assn. Color is shown to be due to formation of nitrosolignin.—*C. A.*

Base-Exchange Capacity Determination of Soils and Other Materials Using Colorimetric Manganese Method. C. A. Bower and Emil Truog. Ind. Eng. Chem.—Anal. Ed. **12:** 411 (July '40). Base exchange material is saturated with divalent manganese, which, after displacement by ammonium acetate, is oxidized to permangate with parasodium periodate and detd. colorimetrically. For saturation and displacement, leaching method may be used, but centrifuge method is preferred by authors. Results on 12 materials checked well with calcium saturation method. Details are given.—*Selma Gottlieb.*

Report on [Analysis of] Waters, Brine and Salt. Fluorine in Water. A. E. Mix. J. Assn. Official Agr. Chem. **23:** 447 ('40). F was detd. collaboratively by Th nitrate method in artificial mineral water and brine soln. and samples critically analyzed by author with view to detg. factors that influence accuracy and precision of results. During evapn. of mineral water, NaOH should be added from time to time to keep soln. alk. Sides of Claissen flask should be insulated by thick asbestos board having hole 1″ in diam. to prevent $HClO_4$ from decompg. with formation of HCl which would distil; for same reason temp. should not be allowed to rise above 135°. As chlorides interfere with distn. by producing HCl, suggested that prelim. detn. of chlorides be made by titration with standard $AgNO_3$ and calcd. amt. of $AgClO_4$ be added to Claissen flask to remove all chlorides. Analyses of mineral water made with and without these suggested improvements showed that results were considerably improved by their use.—*C. A.*

Amperometric Titration of Fluorine With Thorium Nitrate. Alois Langer. Ind. Eng. Chem.—Anal. Ed. **12:** 511 (Sept. '40). Endpoint in titration of fluorine with thorium nitrate can be detd. with dropping mercury electrode. As little as 0.005 mg. of F can be titrated with 0.001 *N* thorium nitrate soln. KCl is used as conducting salt. High Ca or SO_4 or small amts. of Mg interfere.—*Selma Gottlieb.*

The Problem of the Elimination of Fluorine From Drinking Water. Rogelio A. Trelles and Jose M. Bach. Bol. Obras Sanitarias Nacion. (Brazil) **4:** 257 ('40). Use of rain water or purification of spring water by boiling it with 1.5 grams MgO per liter water is recommended for domestic purposes in rural districts. Precipitation of F by lime is economical only if water contains sufficient Mg so that no Mg salts have to be added. 1 gram of bauxite activated at 400–450° during 20 min. adsorbed 4 mg. F if water of pH 5.5 was filtered through it and 1 mg. F if water of pH 8.0 was filtered. Bauxite was regenerated by treatment with 5% NaOH at room temp.—*C. A.*

Methods of Testing for Fluoride. O. M. Smith. Southwest W. W. Jour. **22:** 6: 19 ('40). Great caution should be used in approving or condemning water supply due to amounts of fluoride present in water, because of unreliability of determinations of F and wide variation between results obtained by different methods, particularly in presence of large amounts of certain ions.—*O. M. Smith.*

Routine Method for the Estimation of Fluorides in Natural Waters. R. L. Ford. J. S. African Chem. Inst. **23:** 47 ('40). To 25 ml. of water add 3 drops of mix. of 3 vols. of 1% Na alizarinsulfonate (alizarin S) in EtOH and 2 vols. of 0.4% aq. $Zr(NO_3)_4$ soln. If water is not sufficiently alk. to give pink color of indicator, add dil. KOH soln. sufficient to give color and then add dropwise approx. 0.1 *N* HCl until pink just changes to yellow. Now titrate with standardized $Th(NO_3)_4$ soln. until yellow disappears and is replaced by delicate pink. Run blank detn. and make allowance for it. Method depends upon fact that fluorides decolorize Zr lake of alizarin S but fluoride is pptd. by Th $(NO_3)_4$ and color returns. From numerous analyses, conclusion is drawn that

for detg. F in natural waters this simple procedure gives just as good results as more involved and lengthy distn. method for waters in S Africa.—*C. A.*

The Geo- and Biochemistry of Scattered Bromine. *I. Bromine in Plants and Fresh Water.* L. S. SELIVANOV. Trav. Lab. Biogéochim. Acad. Sci. (U.S.S.R.) **5:** 113 ('39). Water from 11 rivers contained $6.8 \times 10^{-7} \times 8.15 \times 10^{-6}$% bromine, while water from peat bogs, springs and wells contained 2.2×10^{-7} 1.6×10^{-6}%. In rivers, chlorine: bromine:iodine ratio is 8,600 : 27 : 1 and chlorine:bromine ratio is 314 : 1. *II. Bromine in Soils, Silts and Peats. Ibid.* p. 123. For determination of bromine, 25–35 grams of dry plant material was moistened with an alkaline solution, ashed in iron crucible and repeatedly extracted with hot water, eluates being filtered, evaporated, dried and calcined. Residue was dissolved in 10–15 ml. water, neutralized with concentrated sulfuric acid when cool, and placed in oxidizing flask with 1 gram potassium bichromate. By passing air current through solution, BrO_3 was freed and collected in receptacle with 0.5% potassium iodide solution and starch, and titrated with 0.05–0.001 normal hyposulfite solution. Ave. error, 7 γ; min. amount detectable, 5 γ. For determination of bromine in fresh water, 4–5 liters was alkalized, evaporated to 20–30 ml., and worked up like the plant material.—*C. A.*

Estimation of Lead in Drinking Water. C. H. MANLEY. Analyst. (Br.) **65:** 403 ('40). Colorimetric detn. of Pb as PbS presents no difficulty if water is colorless but does if water has distinct brownish tint. Can be overcome by evapg. sample with H_2SO_4, heating until all carbonaceous matter is oxidized, treating with water and EtOH, filtering off $PbSO_4$, dissolving this in NH_4OAc soln. and then applying test with NH_3, NH_4 citrate, KCN and Na_2S soln.—*C. A.*

Detection of Small Amounts of Lead, Copper and Mercury in Drinking Water. Z. M. LEIBOV. Lab. Prakt. (U.S.S.R.) **15:** 10: 21 ('40). Filter sample into 3 100-ml. cylinders. To first cylinder add 5 ml. of $Cr_2O_7^{--}$ and let stand for 1–2 min. Appearance of yellow or orange-yellow turbidity which disappears upon addn. of 20 ml. of 1 *N* NaOH proves presence of Pb. Turbidity which persists after addn. of NaOH points to presence of Ba salt. To second cylinder add 0.2 gram of $NaHCO_3$ (if sample is acid in reaction neutralize 100 ml. with $NaHCO_3$ until yellow color is obtained with methyl orange in sep. test and equal amt. of $NaHCO_3$ is added to cylinder) and 3 drops of 1% soln. of $K_4Fe(CN)_6$. Appearance of brown red color or of ppt. proves presence of Cu salts. To third cylinder add 1 ml. of HCl (1.19) + 2 ml. of 2% $AgNO_3$ soln. + 1 ml. of Sn reagent. Hg salts are present in soln. if milky-white liquid darkens after 0.5–2.0 min. when viewed in disperse light. For detn. of Pb and Cu in amts. smaller than 2 mg./liter view color and turbidity down through liquid on black background and compare it with blank test. For detn. of Hg, blank test must always be performed.—*C. A.*

Copper, Lead and Zinc Content of the Hot Springs of Japan. KAZUO KURODA. Bul. Chem. Soc. (Japan) **15:** 439 ('40). Cu and Fe contents (and Cu:Fe ratios) of water samples from 11 mineral springs of Japan tabulated, as well as Cu, Pb and Zn contents of 12 addnl. water samples from no. of weakly alk. hot springs of Japan, Zn being present in all of latter samples. River water from Ozikagawa, Kawazi and sea water samples from Ito and Senami, resp., contained (mg. per liter); Cu, 0, 0.009, 0.010; Pb, 0.002, 0.004, 0.001; and Zn, 0.036, 0.006, 0.008. For detn. of Cu, 500 ml. of water boiled with HNO_3, treated with excess NH_4OH and 5 ml. of $(NH_4)_2CO_3$ soln., warmed and filtered. The ppt., after washing with warm mixture of 10 ml. water, 1 ml. of NH_4OH (1:1) soln. and 1 ml. of satd. $(NH_4)_2CO_3$ soln., was dissolved in 5 ml. dil. HNO_3 (1:5) and repptd. as before. Combined filtrates, made acid with HCl, were evapd. to dryness, dissolved in HNO_3, adjusted to pH 3 and titrated with dithizone-CCl_4 soln.—*C. A.*

Colorimetric Determination of Iron With Salicylaldoxime. D. E. Howe and M. G. Mellon. Ind. Eng. Chem.—Anal. Ed. **12:** 448 (Aug. '40). Spectrophotometric study indicates that salicylaldoxime can be used for colorimetric detn. of small amts. of ferric iron. Neutral soln. best, pH being critical factor. 0.05 to 10 p.p.m. of iron may be detd. Interfering substances are easily removed; reagent highly specific and no special techniques necessary.—*Selma Gottlieb.*

Determination of Traces of Zinc in Biological Material and Natural Waters. Noel L. Allport and C. D. B. Moon. Analyst. (Br.) **64:** 395 ('39). Traces of zinc are extracted from aqueous solutions with dithizone in chloroform in presence of resorcinol. Method of separating large quantities of heavy metals as sulfides without adsorption of zinc is described. Procedure for determining zinc colorimetrically is detailed, test being sufficiently sensitive to obviate evaporation of large volumes of water. Of commonly occurring metals, only nickel and cobalt interfere.—*C. A.*

Determination of Traces of Aluminum With the Aid of Aluminon. L. M. Kul'berg and E. I. Rovinskaya. Zavod. Lab. (U.S.S.R.) **9:** 145 ('40). Photometric method for determining traces of aluminum (1–10 γ) described. Aluminum is precipitated with hydroxyquinoline, and quinolate is destroyed by dissolving in nitric acid followed by evapn. and ignition. If any iron is precipitated it is extracted with potassium thiocyanate and ether. To 4–5 ml. of aq. soln. contg. aluminum, add 2 ml. 1.5 *N* hydrochloric acid and 1 ml. 5 *N* ammonium acetate, dilute with water to 9 ml., mix thoroughly and add 1 ml. 0.1% aq. soln. of aluminon. Heat to 80° for 10 min. and allow to cool for 30 min. to develop color more completely. Measure color against compensating soln. obtained in making blank detn. for aluminum.—*C. A.*

Colorimetric Analysis of a Two-Component Color System. Harold W. Knudson, Villiers W. Meloche and Chancey Juday. Ind. Eng. Chem.—Anal. Ed. **12:** 715 (Dec. '40). With special reference to detn. of small amts. of aluminum in natural waters low in iron, using hematoxylin method. Using photo-electric filter photometer, 2-component color system may be resolved by using suitable filter to isolate part of absorption band of desired component or by differential separation of absorption bands by 2 appropriately selected filters. Details are given for calculating concn. of one desired component in unknown mix. with second component. Hematoxylin method is modified as follows: Reagents: (1) 35% acetic acid, (2) 20% $(NH_4)_2CO_3$, (3) dissolve 0.1 gram of c.p. hematoxylin in about 100 ml. of boiling water, cool and dilute to exactly 200 ml., (4) 2 grams of soluble starch made into paste and dissolved in 100 ml. of boiling water. Use 50 ml. sample contg. at least 0.05 p.p.m. of aluminum, concentrating if necessary. Add 1 ml. of starch soln., 1 ml. of hematoxylin soln. and mix. Add exactly 1 ml. of $(NH_4)_2C)_3$ and mix thoroughly. After 10 min. add 1 ml. of 35% acetic acid to give pH 4.5 or 4.6. Shake to remove excess of CO_3 formed. Transfer 15 ml. to absorption cell and read in colorimeter immediately, taking series of readings with each filter. Use distd. water, similarly treated, as reference standard and set at 100 on colorimeter scale.—*Selma Gottlieb.*

New Method for the Quantitative Determination of Vanadium in Water. J. M. Bach and R. A. Trelles. Bol. Obras Sanitarias Nacion (Buenos Aires). **135:** 4 (Aug. '40). Frequent presence of vanadium in waters from some of deep formations in Argentina has necessitated search for rapid and sufficiently exact method for quantitative detn. Detn. finally adopted is modification of procedure suggested by Montequi and Gallego for determination of vanadium in soils. Modification has increased sensitivity of original method, making possible detn. in water when present in concentrations as small as 0.05 p.p.m. Procedure recommended follows: Reagents—(1) stock standard solution of vanadium, dissolve 3.807 grams of

sodium metavanadate ($NaVO_3 \cdot 4H_2O$) in 1 liter of distilled water; (2) working standard solution of vanadium, dilute 1 ml. of solution (1) to 100 ml. with distilled water (1 ml. of this solution contains 0.01 mg. of V); (3) o-Oxyquinoline, dissolve 2.5 grams of o-Oxyquinoline in 100 ml. of 10% acetic acid; (4) iso-Amyl alcohol C.P.; (5) acetic acid C.P. (96%). Procedure—if sample does not contain iron, measure 100 ml. of water in Nessler tube, add 5 drops of acetic acid and 5 drops of o-Oxyquinoline solution, mix well, add 10 ml. of iso-Amyl alcohol, shake vigorously for 5 min. and allow to stand until complete separation of iso-Amyl alcohol takes place. Set of 6 standards, containing 1, 2, 3, 4, 5 and 6 ml. of standard vanadate solution made up to 100 ml. with distilled water, are prepared in manner described above for unknowns. Detn. is made by matching color of alcohol layer in unknown with standards. Since iron reacts with o-Oxyquinoline giving green color soluble in iso-Amyl alcohol, it is necessary to remove iron prior to making test. Authors recommend acidifying 100 ml. of sample with 3 drops of acetic acid, heating to boiling, and precipitating with ammonium hydroxide. After filtering off precipitate, detn. is made as described above. For best results following precautions should be observed: (1) sample should be free of turbidity; (2) if it contains much organic matter, add a few drops of nitric acid and bring to boiling; (3) acidity of aliquot should be neutralized with ammonium hydroxide before proceeding with determination; (4) color comparison should be made in Nessler tubes of equal diam.; (5) when sample contains very small amounts of vanadium, standards are made to include 0.05 and 0.075 p.p.m. Absorption of vanadium by iron hydroxide is negligible providing iron concentration is less than 2 p.p.m. Ethyl alcohol may be used instead of iso-Amyl. Sensitivity of test, however, will not be as great as when iso-Amyl alcohol is used. Investigation of effect that ions, commonly found in water, may have upon reliability of test has shown that fluoride, chloride, bromide, iodide, sulfate, nitrate, nitrite, and sulfate do not interfere in concentrations usually found. Sodium, potassium, calcium and magnesium do not interfere in any concentration; manganese does not affect test; copper in concentrations greater than 0.2 p.p.m. gives a yellow color with reagent; titanium also gives a yellow color which may be prevented by adding 3 ml. of 5% sodium fluoride solution; arsenic, lead and zinc do not interfere.—*J. M. Sanchis.*

Determination of Traces of Titanium in Natural Waters. V. T. CHUIKO. Zavod. Lab. (U.S.S.R.) **8:** 950 ('39). Salts of quadrivalent titanium in water in amounts up to 0.001 mg. per liter can be determined by following method. Sufficient soda is added to 1 liter of water to ensure pH value greater than 6 after coagulation with solution containing 80–100 mg. of aluminum oxide. Mixture of water and coagulant, after standing several hr. is filtered and precipitate is dissolved in sulfuric acid, boiled with hydrogen peroxide until colorless, filtered, washed with sulfuric acid and hydrogen peroxide, evaporated until fumes of sulfuric acid are given off, and diluted to 6–10 ml. with sulfuric acid. To this are added 3–5 drops of a reagent, prepared by dissolving 1 gram of thymol in 80% acetic acid and diluting to 100 ml. with concentrated sulfuric acid, and color is compared with standard solution after 30 min.—*W. P. R.*

Starch-Iodide Method of Ozone Analysis. C. E. THORP. Ind. Eng. Chem. —Anal. Ed. **12:** 209 ('40). Method generally used for quant. detn. of ozone in air is to pass air through neutral solution of potassium iodide, acidify solution with acid and titrate with sodium thiosulfate. Author found that sensitivity of method was only 0.0013 mg. of ozone per ml. of 2*N* potassium iodide solution. This was increased to minimum sensitivity of 0.00062 mg. of ozone per ml. of potassium iodide by addition of buffer solution consisting of 5 gm. of aluminum chloride hexahydrate and 1 gram of ammonium chloride made up to one liter; 5 ml. of this solution was added to each 100 ml. potassium iodide solution before test was run. There was

no further acidification during titration. Potassium iodide solution was stable for over 3 hr., and for considerably longer if light were excluded. Apparatus used and precautions necessary are described. Pointed out that only ultra-violet light produces pure ozone. Ozonizers using sparks of any kind will produce impurities in form of oxides of hydrogen and nitrogen amounting to 75% of total yield. Absorption tube containing chromic acid and tube containing potassium permanganate inserted before the potassium iodide absorption bottles will prevent these substances from interfering with estimation.—*W. P. R.*

The Release of Air Dissolved in Water. A. G. Sillitto. J. R. Tech. Coll. Glasgow. **4:** 421 ('39). Discusses solubility of air in water and release of dissolved air on heating. Volume of gas released on heating is not as great as would be expected from study of solubility curves. Shown that air remains in water as supersaturated solution. Rate of liberation of dissolved gas from water when temp. is raised or pressure reduced is increased if surface of vessel containing water is not quite clean, but total amt. of air obtained by boiling is independent of state of surface. When vessel containing water is heated by direct flame instead of in water bath, amount of air liberated increases more rapidly with temp. Connected with phenomenon of "singing" which is due to collapse of steam bubbles formed on hot surface; small air bubbles are left which rise to surface. In "singing" stage, air begins to boil out of solution before boiling point is reached.—*W. P. R.*

Newer Opinions on the Aggressivity of Water. L. W. Haase. Gesundheits Ing. **63:** 104 (Mar. 2, '40). Since Tillman's investigation, has been known that existence of equilibrium $2\ HCO_3^- \rightleftarrows CO_2 + H_2O + CO_3^{--}$ requires certain amount of CO_2, which is called necessary CO_2. If more free CO_2 is present, excess is aggressive CO_2. Work of Tillman, Strohecker, Langelier, De Martini, Mohler, Arbatsky and Tregl is discussed. Differences exist between investigators in method of determination of amount of aggressive CO_2 and also inaccuracies occur in some of determinations needed, such as pH, titration for total free CO_2, and amount of carbonate. Most methods consider only calcium and carbonate hardness whereas total equilibrium is also affected by magnesium ions and by non-carbonate hardness. Besides this there is an aggressiveness depending on solubility of iron. In oxygen-free water this depends solely on pH, in water containing oxygen, temp. and movement of water, as well as biological processes, also have an influence.—*Max Suter.*

Colorimetric Method for Determination of Nitrite. Martha B. Shinn. Ind. Eng. Chem.—Anal. Ed. **13:** 33 (Jan. '41). Present *Standard Methods* procedure for nitrite depends on diazotization of sulfanilic acid by nitrite present followed by coupling with α-naphthylamine. Reaction relatively slow, color unstable and standards unstable and difficult to prepare. Sulfanilamide can be substituted for sulfanilic acid; it is more stable than latter, both dry and in soln., and reacts more rapidly in coupling process. For coupling agent *N*-(1-naphthyl)ethylenediamine dihydrochloride can be used. It is water soluble, decreases time for color development to 2 min., giving color stable for several hr., and is less sensitive to variations in pH, reacting equally well in acid concns. from 0.1 to 1 *N*. Range of method is 0.0025 to 0.05 p.p.m. of nitrite. For method to succeed, excess of sulfanilamide must be allowed, large excess causing no interference. Since sulfanilamide solns. are more stable than nitrite solns., known sulfanilamide solns. are used as basis of standards. *Reagents*: Sulfanilamide, 0.2% in water. Will keep at least 1 mo. in refrigerator. HCl, 1 + 1 diln. of concd. acid. Sodium nitrite, 0.1% soln. (approx.) will keep 1 wk. or longer in refrigerator. Ammonium sulfamate, 0.5% soln. in water. Coupling agent, as above, 0.1% in water, kept in dark bottle. *Procedure*: To neutral or acid sample of not over 35

ml., add 1 ml. of 50% HCl, 5 ml. of 0.2% sulfanilamide soln. and let stand 3 min. Add 1 ml. of ammonium sulfamate soln. After 2 min. add 1 ml. of coupling reagent and dilute to 50 ml. At same time prepare standards in 50-ml. volumetric flask with 5 ml. of 1:100 diln. of 0.2% sulfanilamide. Add 1 ml. of 50% HCl, 1 ml. of 0.1% $NaNO_2$ and about 5 ml. of water. Allow to stand 3 min., add 1 ml. of ammonium sulfamate soln. to destroy excess nitrite, let stand 3 min., add 1ml. of coupling agent and dilute to volume. Read sample vs. standard in colorimeter. Directions given for standardizing sulfanilamide solution against assayed nitrite soln.—*Selma Gottlieb.*

Nitrite Nitrogen Standards. W. F. REINDOLLAR. Ind. Eng. Chem.—Anal. Ed. **12:** 325 (June '40). Sodium nitrite, sufficiently pure for primary standards in nitrite nitrogen detns., is readily available commercially and is more convenient than silver nitrite. Sodium nitrite is relatively inexpensive and the solutions are readily prepared fresh as needed.—*Selma Gottlieb.*

The Azo-Xylidic Reagent and Nitrites. FRANCISCO C. ALZAMORA. Bol. Soc. Quím. (Peru) **5:** 240 ('39). Sensitive reagent for detection of 2.84×10^{-6} grams sodium nitrite per ml. is prepared as follows: Solution A: xylidine acetate, 1.81 grams, acetic acid, 10 ml., water to 1 liter; Solution B: β-naphthol, 2.65 grams, sodium hydroxide, 10 grams, water to 1 liter. Place 50 ml. of sample and 1 ml. of Solution A in Nessler tube, shake and let stand 5 min.; add 5 ml. Solution B. Red-orange color is formed which can be used for determination of nitrites in water.—*C. A.*

Washing Reclaimed Silver Nitrate Crystals With Alcohol Leads to Explosion. JOHN P. TULLY. Can. Chem. and Process Indust. **25:** 2: 90 (Feb. '41). Silver chloride residues from routine Mohr titrations of sea water are saved in Pacific Biol. Sta. at Nanaimo, B. C. About 20 lb. of chloride accumulates each yr. and is subjected to reclamation process in successive lots of 2 lb. each. Residues fused with sodium carbonate, and molten metal separated from slag by pouring into water. Further purif. effected by remelting and pouring into water second time. Resulting mossy silver treated with cold concentrated nitric acid, which is heated to boiling as rate of reaction decreases. Impure silver nitrate solution contains chromium, carried over from original residues, iron and copper, from fusion manipulations, and excess nitric acid. Liquor evaporated under partial vacuum until crystals of silver nitrate separate, then cooled, supernatant liquir decanted, and crystals washed once with small amount of distilled water—process being repeated successively until liquor vol. reduced as much as practicable. Residual silver precipitated as chloride and preserved until next reclamation. Aqueous liquor contains practically all excess nitric acid and nitrates of less noble metals. Practice was then to rinse moist crystals, with adhering traces of metallic impurties and dilute nitric acid, 2–4 times with ethyl alcohol (denatured with 10% acetone). Alcohol added to crystals first obtained, mass stirred, allowed to settle and alcohol decanted to second lot of crystals and so on. Silver generally recovered from alcohol by precipitation as chloride or by evaporation to dryness. Alcohol washing repeated until desired appearance of crystals obtained, crystals then being set in warm place to dry. In Oct. '40, series of washings completed and lab. asst. examining last lot of alcohol-moist crystals when explosion occurred, causing considerable damage and severe bodily injuries. After explosion, strong odor of ethyl nitrate in lab. No doubt, silver fulminate was formed according to reaction: $AgNO_3 + HNO_3 + C_2H_5OH \rightarrow AgONC + ?$. Alcohol washing may be obviated in several ways, depending on required state of reclaimed salt: (1) If acidity of crude solution is only objectionable characteristic, may be neutralized with sodium bicarbonate solution until faint precipitate of silver carbonate appears. Whole solution then boiled to expel free carbon dioxide and more bicarbonate solution added until faint precipitate

persists at boiling point. (2) If required to reduce concentration of heavy metal nitrates, crystals from acid solution may be dissolved in water, made up to about 5 *N*, and solution neutralized as above. (3) If necessary to remove heavy metals but alkali metals are not objectionable, crude crystals may be rinsed with saturated solution of sodium or potassium nitrate, as described under alcohol technique. (4) Pure crystals may be obtained by recrystallizing alkali nitrate-washed crystals from distilled water.—*R. E. Thompson.*

Methods for the Detection of Toxic Gases in Industry. ANON. Leaflet No. 10. *Chlorine.* Dept. Sci. & Ind. Res. (Br.) ('40). Describes simple, rapid, and straightforward method of estimating concentrations of chlorine in air. Air is sampled by drawing with hand pump through bubbler containing ortho-tolidine solution until depth of color produced in solution is equal to one of a series of color standards prepared from potassium dichromate solution. Concentration is obtained by referring number of pump strokes to table of concentrations contained in leaflet. Claimed that concentrations as low as 1 p.p.m. are demonstrable by method. Brief review of industries in which chlorine may be encountered and effects of exposure to different concentrations is included.—*B. H.*

APPLICATION FOR MEMBERSHIP
IN THE
AMERICAN WATER WORKS ASSOCIATION
22 EAST 40th ST., NEW YORK

Date:.....

..... hereby make application for
(I or We)

.....
(Active, Junior, Corporate or Associate Membership, or Affiliate)

in the American Water Works Association, and enclose herewith the sum of $....., one year's dues in advance.

Name.....

Company or Department.....

Title or Position.....

Address.....

.....

If application is for Junior Membership, give date of birth.....

If application is for Affiliate, state number of active services in property where employed.....

Nature of business or character of work (for office records).....

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If application is for Corporate or Associate Membership, it must be signed by the person designated to represent the firm or corporation in A.W.W.A. activities.

.....
Signature of Applicant.

Application obtained by:

.....

(over)

ARTICLE I OF BY-LAWS

Section 3. An Active Member shall be a superintendent, a manager, an official or employee of a municipal or private water works; a civil, mechanical, hydraulic, or sanitary engineer, a chemist, a bacteriologist, or any qualified person engaged or interested in the advancement of knowledge relating to water supplies. (Annual Dues, $10.00.)

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Section 7. An Affiliate shall be any person otherwise qualified for Active membership who, at the time of application, is not nor previously has been a member of the Association and who, for acceptable reasons, does not wish to become an Active Member.

No corporation, firm or partnership which otherwise would be entitled to the grades of Associate or Corporate member may hold the grade of Affiliate. No employee of an Associate member may become an Affiliate. No person who is the superintendent, the manager, the chief engineer, the superintendent of filtration, the chief chemist, or the superintendent of distribution in a plant having more than 3,000 active services, is eligible for the grade of Affiliate. Under unusual conditions, exception to the above may be made by action of the Executive Committee if the applicant sets forth fully the reasons for the exception when applying for the Affiliate grade.

Affiliates shall not be entitled to vote upon general Association questions, and not eligible to hold office in the Association, nor in any of its Divisions. They shall be eligible to vote upon Section questions and to hold Section offices except those of Chairman, Vice-Chairman, Secretary (and/or Treasurer). They shall be entitled to all other rights and privileges of Active Members. Affiliates receive the March, June, September and December issues of the Journal each year. (Annual Dues, $4.00.)

Memberships will be dated as of the beginning of the quarter in which the application is received.

Membership in the Association carries, also with no additional dues, membership in its Local Sections and National Divisions, and includes the Journal, a monthly publication devoted to water works interest. The proceedings of the annual conventions and of the meetings of the Local Sections are published in the Journal, which also contains contributed articles on subjects pertaining to public water supplies.

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Toronto's New Purification Plant and Pumping Station

By A. U. Sanderson and L. F. Allan

THE Victoria Park Water Purification Plant (Fig. 1) takes its supply from Lake Ontario, east of city limits, and discharges its effluent partly to the distribution system, directly through high lift pumps, and partly through a filtered water tunnel to the John Street Pumping Station (Fig. 2).

The plant site is protected from the lake by a retaining wall along the entire south boundary of the property. A groyn constructed as part of the wall, contains a 54-inch surge overflow conduit from the intake well in the pumping station and a 54-inch main drain from the plant.

The intake section consists of a tee with a 20-foot diameter circular inlet, an 8-foot intake pipe connected to the south branch of a three-way distributor, a 10-foot shaft and tunnel, an intake well, screen wells and suction chambers.

The north end of the intake is designed to draw in water horizontally and is 4 ft. high, protected with $2\frac{1}{2}$-inch vertical steel bars at $15\frac{1}{2}$-inch centers. The intake pipe has a steel membrane with gunite lining and concrete cover, is laid in a trench and is bolted together in sections 100 ft. long. The tunnel is horse-shoe shaped, constructed in rock and lined with concrete.

A paper prepared by A. U. Sanderson, Chief Engineer of Water Supply, and L. F. Allan, Engineer, and published by the authority of R. C. Harris, Commissioner of Works, all of the Department of Works, Toronto, Canada.

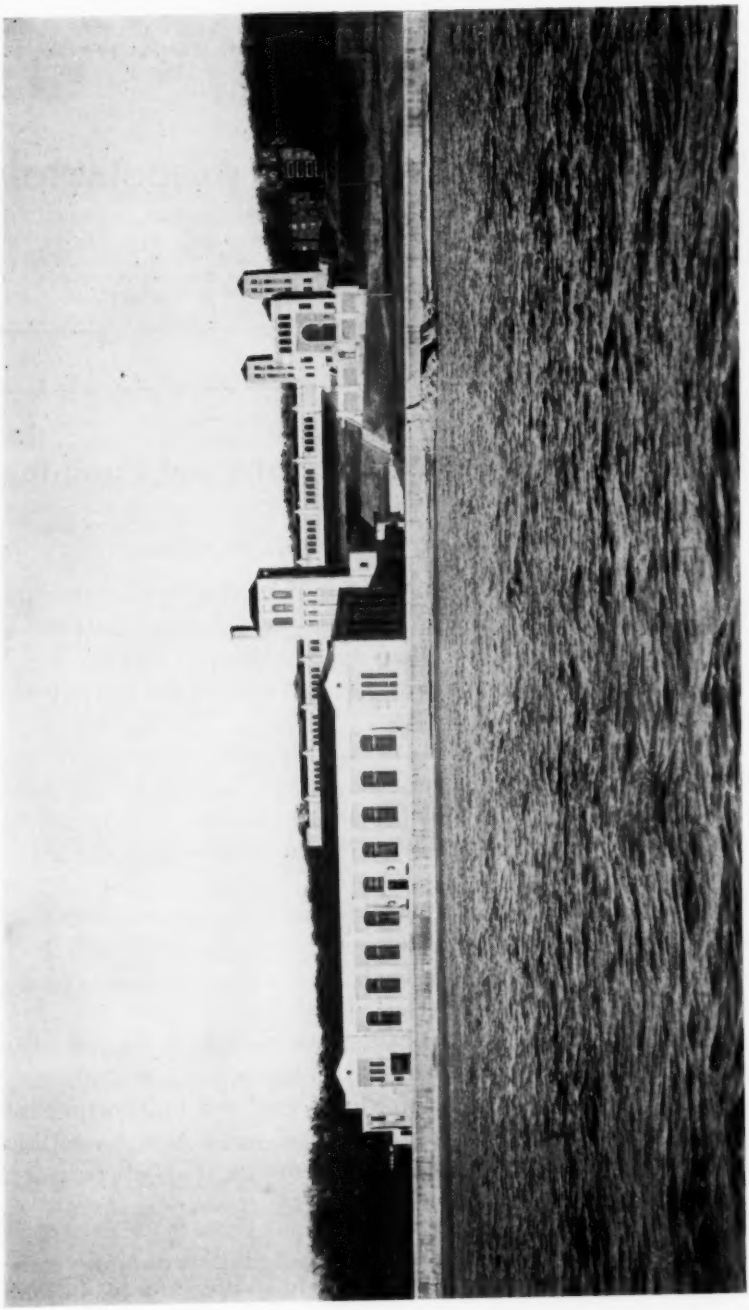

FIG. 1. Victoria Park Water Purification Plant

The vertical revolving screens are housed in individual chambers which may be isolated by motor-operated sluice gates on the inlets and outlets. The screens are arranged in two rows, one on each side of the intake well.

The suction conduits are 84 in. in diameter and are in duplicate. Each raw water suction conduit has it own suction chamber and bank of screens and the raw water pumps are arranged so that approximately 50 per cent of their capacity is connected to each conduit.

The pump discharge pipes are 42 in. in diameter and connect to two 80-inch conduits leading to the mixing chambers and settling basins.

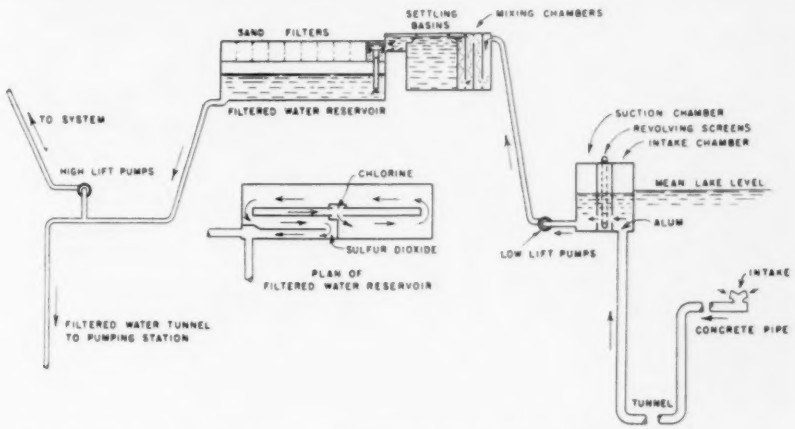

FIG. 2. Hydraulic Flow Diagram of Victoria Park Purification Plant and Pumping Station

These conduits are circular between the pumping station and the overflow chamber at the filter building, and then rectangular to the mixing chambers.

The combined mixing chambers and settling basins are three in number. The mixing chambers are of the spiral-mix type and each chamber is divided into twelve compartments arranged in rows of three in series. The inlets and outlets from the compartments are alternately at the top and bottom at the side walls to give tangential flow. At the normal rate of 100 m.g.d.* the time of mixing is 40 min. and the time of settling 170 min. The outlets from the mixing chambers and settling basins are a system of ports designed to produce

* All values in gallons throughout this paper refer to Imperial gallons (1 Imperial gallon = 1.2 U. S. gallons).

uniform distribution of flow. Rectangular concrete conduits outside and along the north and south walls of the filter building conduct the settled water to the filters; and the drain conduits for the waste wash water are located at a lower elevation on the same walls. Locating these conduits outside the building permits a much smaller central gallery (Fig. 3).

FIG. 3

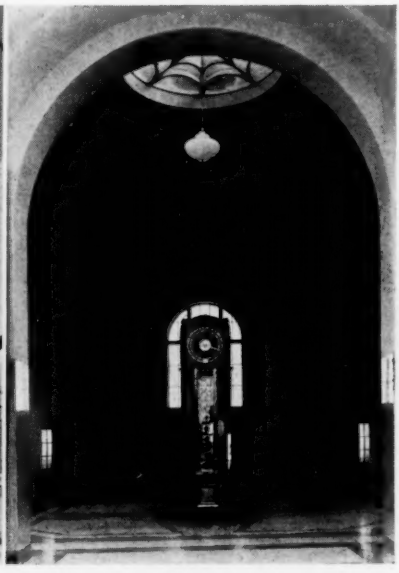

FIG. 4

FIG. 3. Filter Gallery at Victoria Park Purification Plant
FIG. 4. End of Filter Gallery; showing signal pylon

Filtration and Pumping Equipment

There are 20 filters, each approximately 68 ft. by 36 ft. in size with a net filtering area of 2,103 sq.ft. each (Fig. 5). At the standard rate of 105 m.g.d. per acre they will deliver a total of 100 m.g.d. As the filters are unusually large, particular attention has been given to the design of the wash water system in order to secure an even distribution of wash. The underdrain system for each filter consists of a concrete conduit, 3 ft. square in cross-section, constructed integral with and underneath the filter floor and along its center line. The wash water enters this conduit and passes upward, through fourteen rectangular ports into a rectangular distribution concrete manifold.

These ports are designed to compensate for the varying conditions of flow. The cast-iron underdrain lateral pipes are designed to secure equal flow through each orifice and are tapered from 4 in. in diameter at the inlet end to $2\frac{1}{2}$ in., with ends connected to an equalizing pipe. The orifices are brass nozzles of $\frac{3}{4}$-inch bore, spaced at 12-inch centers in both directions. The filter unit consists of a 20-inch layer of gravel graded in six layers, from 3 in. down to coarse sand, and a 26-inch layer of sand having an effective size of about 0.55 mm. and

FIG. 5. Filters at Victoria Park Purification Plant

a uniformity coefficient of about 1.5. The filters are equipped with visible effluent comparators and rate controllers having manual and master control. When the elevation of the water in the reservoir is within 1 ft. of the over-flow, the master controller is regulated through a float control from reservoir elevations. The filter gallery has been enclosed with glass screens to conserve heat and reduce condensation.

The clear water reservoir of 12 mil.gal. is located beneath the filters. The water flows from the filters into a rectangular conduit within the reservoir and discharges into the latter through a rectangular Venturi meter. The reservoir is divided by baffle walls so that the water makes a complete circuit before entering the 80-inch filtered water conduits leading to the high lift pumping station and

to the filtered water tunnel to the John Street Pumping Station. Chlorine is applied at the outlet of the Venturi meter and sulfur dioxide for de-chlorination is added near the reservoir outlet. The time of contact with chlorine is about 80 min.

In the rotunda at the end of the filter gallery there is a signal pylon (Fig. 4) on which are mounted four illuminated dials, colored signal lights for use in the control of wash water, and the manual lever for setting the master rate control. The dials indicate time, reservoir level and total rate of filtration.

The wash water system comprises three pumps of 10, $7\frac{1}{2}$ and 5 m.g.d. capacities in the pumping station, two 70,000-gallon tanks in the filter building and signal lights on the pylon. The controls are arranged so that any or all of the pumps may be operated manually or automatically from float switches at the tanks. The colored signal lights indicate low, medium and high water elevations in the tanks. If the pumps fail to cut out automatically at high water level an alarm rings in the control room in the pumping station.

The chemical solution control equipment, in the filter building, comprises three 2,200-pound and one 750-pound manual control vacuum type chlorinators, two 2,200-pound and one 750-pound manual control vacuum type sulfonators, four evaporators, four scales and an overhead electrically-operated traveling hoist for handling one-ton containers. This equipment provides ample spare capacity, with evaporators and manifolds in duplicate. The storage room is equipped with a water spray system and the chlorine room with a ventilating system and gas-proof doors.

The chemical building, which is part of the service building, contains chemical dry feed machines, alum storage bins, a chemical storage room and a pneumatic conveyor. The chemical dry feed machines consist of two belt type gravimetric alum feeders having capacities of 2,000 lb. to 20 lb. per hr. and one batch type gravimetric feeder with a capacity of 1,000 lb. to 20 lb. per hr. for feeding other chemicals. The feeders are equipped with integrators and recorders and with alarm bells to warn the operator if the rate of feed varies too much from the set rate. The two alum storage bins have a capacity of about 170 tons each. The pneumatic conveyor for elevating alum to the bins is of the suction type and has a capacity of more than 7 tons per hr. of ground alum. The chemicals are mixed in lead-lined chambers with internal mixing jets and are carried to the suction well through 2-inch lead pipes.

The heating plant is located in the service building and consists of two 150-horsepower horizontal-return tubular boilers operating at 60 lb. per sq.in. pressure. The boilers are fired with heavy oil through steam atomized burners. Auxiliary equipment comprises oil heaters, oil meters, electric- and steam-operated fuel oil pumps, electric- and steam-operated boiler feed pumps, steam flow meter, draft gages, a recording flue gas thermometer and an automatic fuel feed regulator.

Two suction headers for the high lift pumps are fed from the reservoir, which is about 60 ft. higher, and one high lift pump for each district is connected to each header.

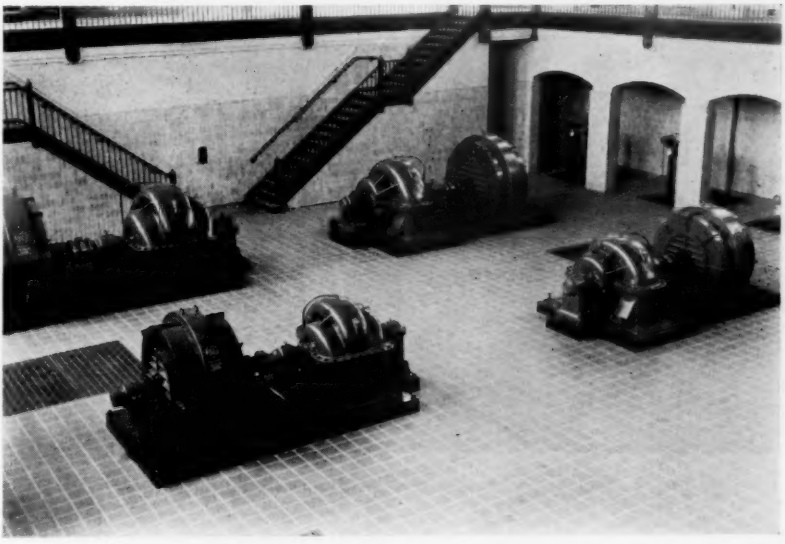

FIG. 6. Low Lift Section of Victoria Park Pumping Station

The capacity of the filtration plant is now 100 m.g.d., but provision has been made in the design for doubling this capacity by extending the filter building and settling basins. The pumping station is constructed for its ultimate capacity and when the filtration plant is extended it will be necessary only to add new pumping units.

The pumping equipment comprises four synchronous motor-driven low lift pumps (Fig. 6) with capacities of 50, 40, 25 and 20 m.g.d.; four synchronous motor-driven high lift pumps (Fig. 7), two having capacities of 25 m.g.d. for District No. 2 and two, of 5 m.g.d.

for District No. 1; and three induction-motor-driven wash water pumps of 10, $7\frac{1}{2}$ and 5 m.g.d.

In the design and construction of the pumps and motors everything possible was done to produce highly efficient units. For instance, the elbows of the series piping on the high lift pumps were flattened to reduce friction loss. The air for ventilating the motors is drawn in just above floor level and discharged below for heating the basement.

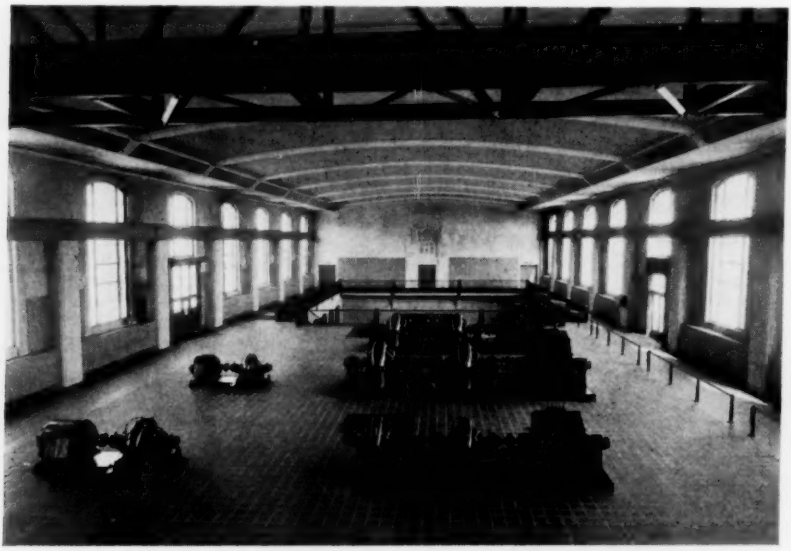

FIG. 7. High Lift Section of Victoria Park Pumping Station

Electrical and Control Equipment

The electrical equipment consists of: 13,200/2,300-volt, 2,300/550-volt and 550/110-volt transformers; 13,200-volt, 2,300-volt and 550-volt metal-clad switchgear; three service switchboards (one in each building); a relay board; a control benchboard; and auxiliary equipment.

To facilitate repairs and ensure continuity of service, each bus is divided into sections so that any section on which trouble may occur can be isolated without shutting down the entire plant. The 13,200-volt bus and the 2,300-volt bus are each divided into three sections and the 550-volt bus into two sections with the necessary isolating switches. Ultimately each 13,200-volt bus section will be fed with a

separate feeder, two of which have already been installed. A 3,500-kv.amp. transformer is connected, with duplicate cables, between each section of the 13,200-volt bus and a corresponding section of the 2,300-volt bus. The load connected to the 2,300-volt bus is divided among the three sections, so that if one section is out of commission, there will always be some wash water, high lift and low lift pumps available. Each section is provided with an exciter set. The same principle is applied to the service buses.

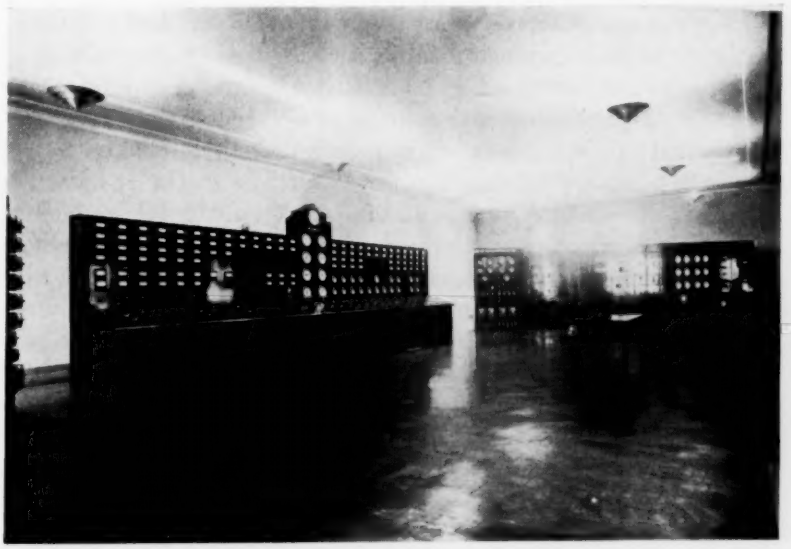

FIG. 8. Control Room at Victoria Park Pumping Station

The 13,200-volt transformers and switchgear are located in a separate building and the smaller transformers are housed in separate rooms in the pumping station, service building and filter building. The 2,300-volt and 550-volt switchgear, the exciter sets, battery, contactors, field rheostats, relays, pumping station service board and control bench board are located in the control section of the pumping station. The cables are carried in metal pans or conduit in shafts, tunnels and basements of the pump rooms.

Control of equipment has been centralized as far as possible in the control room (Fig. 8), which contains the bench board, relay board and pumping station service board. From the benchboard the operator can operate the pumps, oil circuit breakers, disconnecting

switches and all pump discharge valves. All information necessary for the operation of the plant is indicated on the board, including water elevations of the intake well, settling basins, reservoir and wash water tanks, water pressures in Districts No. 1 and No. 2, total raw water flow, filtered water tunnel flow, other Venturi meter readings and valve position indications. The board is also equipped with all necessary electrical instruments for indicating the performance of the various electrical units. All motors, circuit breakers, disconnecting switches, rheostats, discharge valves, etc. are operated by means of miniature control switches and a 60-cell control battery. Many of the controls are automatic, such as those for the starting of the synchronous motors, which go through the various steps by means of suitable relays following the closing of the control switch. When it is desired to open, close or adjust the setting of a discharge valve, it is only necessary to close a control switch until the operation is complete. During this operation the position of the valve is shown on an indicator on the control board. Safe operation of the motor-driven disconnecting switches is assured by electrical interlocks with other switches and circuit breakers. A miniature bus on the benchboard shows the relationship between the various elements of the electrical and hydraulic systems. All electrical equipment is fully protected with relays against the usual operating hazards, such as overload, undervoltage, etc. The oil circuit breakers can be removed from the structure for repairs by mechanical means and the operation is made safe by suitable interlocks. After removal, the openings in the structure are closed with safety shutters.

The electrical equipment also includes a signal panel on the wall of the low lift pump room, whereby the operator indicates the pumps to be started or stopped, an alarm and annunciator to give warning of certain events, an emergency motor generator set for operating the Selsyns and electric clocks, and an automatic throw-over switch for emergency lighting in case of power failure. Air circuit breakers are of the de-ion type and all protection of lighting circuits and small motors is by "No-fuze" switches.

The mechanical equipment was selected for maximum convenience of operation and to this end the hydraulic discharge valves may be operated electrically from the control room and hydraulically from pump control cabinets. The position of the valves and the flow indications of the Venturi meters are transmitted to the benchboard by means of Selsyns and Chronoflo instruments. The Venturi-

meter registers, valve control apparatus, and pressure gages are mounted in pump control cabinets in the pump room. Each cabinet includes an emergency stop button and a signal number and light to indicate when the pump is running. Each pump is provided with a tilting disc check valve with oil dash pots, hand-operated suction gate valve, hydraulically-operated discharge gate valve on the low lift and cone stop valves on the high lift. The 60-inch gate valves on the suction headers within the station are motor-operated from a point near the valve. The mechanical equipment also includes priming pumps, air compressor, automatic and emergency sump pumps, eductors, etc.

The consulting engineers were H. G. Acres & Co., Ltd., and Gore, Nasmith and Storrie. The project was carried out under the direction of R. C. Harris, Commissioner of Works, with George G. Powell as Deputy City Engineer.

At the present time the City is served by the Island Filtration Plant which consists of a slow sand plant with a normal capacity of 40 m.g.d. and a drifting sand mechanical plant with a normal capacity of 60 m.g.d. The slow sand plant was placed in service in 1912 and the mechanical plant in full operation in 1918. The Toronto system as a whole was described by R. C. Harris (Jour. A.W.W.A., **21:** 1609 (1929)) at the 1929 Convention which was held in Toronto.

Factors in Control of Reservoir Silting

By Carl B. Brown

MUCH of the public water supply of the United States comes from impounding reservoirs. Not only such great cities as New York, Boston, Baltimore, Birmingham, Dallas, Denver, Seattle, San Francisco, and Los Angeles depend on reservoir systems, but innumerable smaller cities and towns throughout the country derive their water from such sources. More than 2,600 dams have been constructed in this country to impound water for public or industrial supply at a cost of more than $463,000,000, exclusive of appurtenant water works and distribution lines. About 25,000,000 persons or nearly 20 per cent of the population of the United States obtains its domestic water from these storage reservoirs.

Among the more important, and one of the least considered, problems in the development and maintenance of impounding reservoirs is the loss of storage capacity by silting. Examination of a number of textbooks on water works engineering written during the last ten years reveals only a very cursory treatment of this problem, despite the fact that engineers, from time to time for many years, have called attention to silting problems in this or that water supply reservoir, as well as in reservoirs constructed for power, irrigation, recreation, and navigation.

Agricultural specialists, on the other hand, long ago recognized that exploitative deforestation, forest fires, overgrazing, cultivation of oversteep slopes, improper methods of tillage, and other unwise agricultural practices caused greatly accelerated soil erosion, which resulted in a large increase in the sediment load of streams.

Moreover, it has long been taken for granted that a cause and effect relationship must exist between accelerated soil erosion and high

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A paper to be presented at the Toronto Convention, June 23, 1941, by Carl B. Brown, Head, Reservoir Section, Sedimentation Division, Soil Conservation Service, Washington, D. C.

FIG. 1. Lake Como at Hokah, Houston County, Minn., in 1926; impounded in 1922 for water power and recreation

FIG. 2. Lake Como in 1936; completely filled with sediment from soil erosion on watershed

rates of reservoir silting. Steps have been taken only recently, however, to determine the extent to which the tremendous investment in our reservoirs is being affected by silting, the degree to which present rates of silting are caused by acceleration of erosion, and the measures that may be adopted to decrease silting where it is causing excessive damage.

Work of Soil Conservation Service

In 1935, Congress created the Soil Conservation Service as a permanent agency of the United States Department of Agriculture in order "to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods,

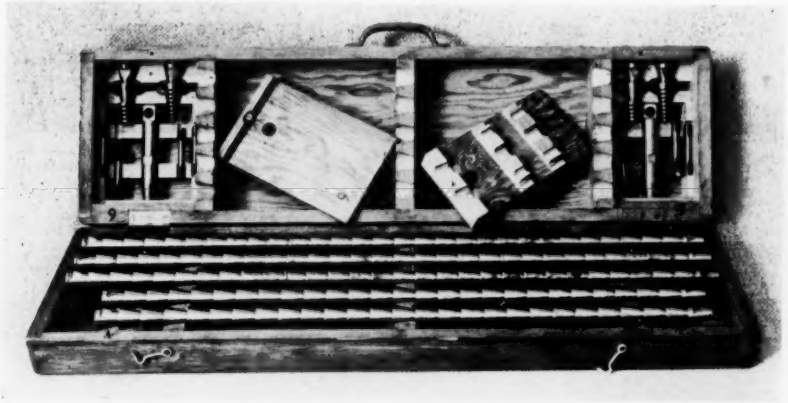

FIG. 3. Sectional Spud for Measuring Thickness of Sediment in Reservoirs

prevent impairment of reservoirs, . . ." (1). In conducting the research authorized by this act, the Soil Conservation Service established a Sedimentation Division to determine the character and extent of downstream damages resulting from soil washed from upland slopes, and the nature and location of control measures required to ameliorate these damages. Reservoir silting is one of the principal problems being investigated by this Division. The study of the problem includes inventorying the reservoir resources of the country, determining, by surveys of representative reservoirs, the amount and rate of damage by silting, establishing the relationship of silting to soil erosion and to the transportation of sediment within the watershed, and considering the methods available for combating the silting damage.

Two types of reservoir surveys have been made. The reconnaissance survey has been designed to determine the approximate rate of loss of storage capacity, and consists of measuring the thickness of sediment at from 15 to 50 or more well-distributed locations in the reservoir by means of a simple measuring device known as a spud (Figs. 3 and 4). Using simple formulas, the ratio of sediment volume to the original storage capacity may be estimated. Adequate reconnaissance examinations of moderate-sized reservoirs, up to about 10,000-acre-foot capacity, can be made by a specialist in this work in

FIG. 4. Soil Conservation Service Reservoir Survey Party on Lake Dallas, Tex.; showing man holding spud and pointing to upper level of silt retained in cups and second man pointing to division line between silt above and "old soil" below

one day with one helper and a motor boat. The results provide a satisfactory basis for estimating the order of magnitude of the remaining life of the reservoir, such as 10, 20, 50, or 100 years.

The detailed reservoir survey, on the other hand, involves a standardized engineering measurement of the original and present capacities of the reservoir as well as the sediment volume. A complete description of the methods used in making the detailed surveys is contained in a publication of the United States Department of Agriculture (2).

These detailed surveys differ from reconnaissance surveys not only in their much higher degree of accuracy, but also in the fact that all survey stations are monumented to permit future repeat surveys on an exactly comparable basis, thus providing checks on the progress of sedimentation at such intervals of time as may be considered desirable. Furthermore, the data from these detailed surveys are of sufficient accuracy to be used in calculating indices of sediment

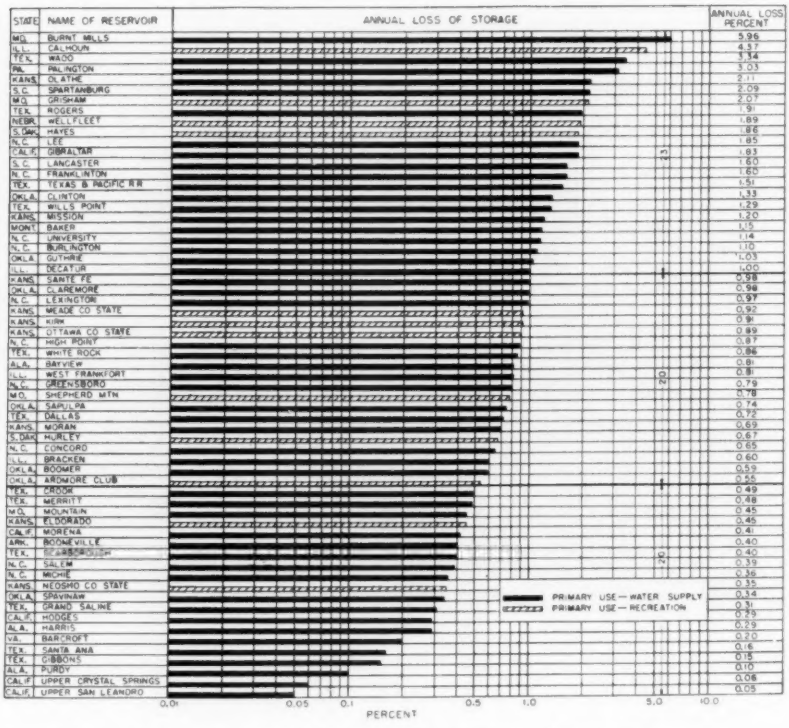

FIG. 5. Annual Rates of Silting in U. S. Water Supply Reservoirs

production or net erosion from the watershed in terms of cubic feet per acre annually, or in any similar units. These computed "indices of erosion" may be used by extrapolation in estimating the probable rates of sediment delivery from adjacent or similar watersheds, and are considered more accurate for this purpose than are short-term records of the suspended load of streams determined by sampling. Detailed surveys require the services of four or five men, and take up to three weeks on reservoirs of less than 10,000-acre-foot capacity.

To date (May, 1941) data have been obtained on silting in about 450 reservoirs in 36 states, about four-fifths of them surveyed by the Soil Conservation Service during the last six years. Detailed surveys have been made on about 150 reservoirs, and reconnaissance surveys on the remainder. Of the 450 reservoirs on which silting data are available, 151 are used primarily for public water supply.

Figure 5 shows in graphical form the rates of silting in all water supply reservoirs for which the Soil Conservation Service has made detailed surveys. These reservoirs represent a fair cross-section of the whole country, except that the New England States and the Pacific Northwest are not proportionately represented; and as these sections have generally less serious reservoir silting problems than do other sections, the average rate of silting based on this sampling may be slightly high. Figure 5 shows that slightly more than one-third of the reservoirs surveyed are losing their capacity at a rate of more than 1 per cent annually, while slightly less than one-third are losing from $\frac{1}{2}$ to 1 per cent, and an equal number less than $\frac{1}{2}$ per cent annually.

Significance of Silting Problem

In order to analyze the significance of the silting problem in terms of the average life of all water-supply reservoirs in the country, three assumptions are made:

1. That decrease of capacity to 20 per cent of that originally provided will, on an average, terminate the useful life of a reservoir.*
2. That the rate of silting will remain generally uniform until 80 per cent of the storage capacity is gone.
3. That the 151 water supply reservoirs on which data are now available represent a fair cross-section of conditions over the whole country.

Based on these assumptions, it appears that, as a result of silting alone, 21 per cent of the nation's water supply reservoirs will have a useful life of less than 50 years; another 25 per cent, 50 to 100 years;

* The assumption of 80 per cent of the original capacity may be too conservative. An investigation by A. N. Garin, Economic Research Division, Soil Conservation Service, of 17 water supply reservoirs in the Trinity watershed of Texas indicated a range from 38 to 85 per cent and an average of 60 per cent. If it were assumed that 60 per cent of the original capacity would terminate the useful life of the average reservoir, 32 per cent of the nation's water supply reservoirs would be useless in less than 50 years and another 22 per cent in less than 100 years.

whereas only 54 per cent will provide enough storage to suffice for present requirements (not the estimated future needs) 100 years hence.

This will serve to indicate the magnitude of the silting problem. Still to be considered, however, is the question of what, now, can be done to lessen the present rate of damage and minimize this hazard, which is not only impairing the enormous investment already made in reservoirs, but threatens to destroy the irreplaceable and virtually invaluable reservoir sites.

Methods of Silting Control

A common proposal has been to clean out the impounding reservoir by some engineering method, such as pump dredging, sluicing through the dam, or dragline excavation. Although cleaning out may be the only alternative in rare instances, it has in a great number of cases been found to be too costly for general consideration even when physical conditions provide some place for disposal of the sediment where it will cause no further harm. For example, the estimated average original cost of storage space in the water supply reservoirs of Maryland and Pennsylvania is $51 per acre-foot, or slightly more than 3 cents per cubic yard. The cost of removal of any considerable quantity of accumulated sediment by any available engineering methods may be expected to be 5 to 50 times as much per cubic yard.

The most extensive reservoir dredging operation undertaken in the past few years is that on White Rock Lake at Dallas, Tex., the use of which, as a source of water supply, was discontinued in 1928, partly because the greater demands of a growing city required a larger reservoir, but also, in no small measure, because silting reduced its capacity by more than 15 per cent in 18 years. After 1928, White Rock Lake rapidly became a popular recreational spot and has enhanced the value of nearby property by an estimated $10,000,000. By 1937, silting and unhealthful swamping of a large area in the upper part of the lake led to construction of an 8-inch hydraulic dredge for the purpose of cutting channels through the reservoir delta and dumping the sediment on islands which could be beautified for recreational use. Records of this dredging show an operating cost of 12 to 13 cents per cubic yard moved. Including capital investment, depreciation, and supervision, the total cost has been estimated at about 25 cents per cubic yard. It should be remembered, moreover, that sediment was not moved out of the reservoir, but was moved only a few hundred feet on to the silt islands.

Costs of cleaning debris basins in Southern California by power shovel and trucking the material for not more than one mile have averaged 30 cents per cubic yard. Experience of the Soil Conservation Service in excavating farm ponds has indicated minimum costs of 10 to 15 cents per cubic yard with drag scraper and team, where the excavated material was dragged or hauled at most only a few hundred feet on to the dam. Costs on large-scale river- and harbor-dredging projects of the Army Engineers have ranged from averages of 10 to 25 cents per cubic yard for different sections of the country.

FIG. 6. Oakdale Mill Dam near High Point, N. C., Completely Filled with Sediment; showing small amount removed by complete drawdown

Efforts to flush sediment out of an impounding reservoir by opening sluice gates or other outlets of the type built into dams in this country have succeeded in removing only a small fraction of the accumulated material, less than 5 per cent in cases of record, except where the use of the reservoir was discontinued for one or more years during which stream action was able to carve out a channel through the sediment and re-establish its original stream grade.

The three generally feasible approaches to reservoir silting control are: (1) adequate consideration of the silting factor in the original location and design of the dam; (2) a plan of water release designed

to vent the largest possible amount of sediment before it has an opportunity to deposit and compact; and (3) watershed protection through land purchase or co-operation with land owners to control soil erosion.

Location and Design of Reservoirs

In considering location and design, it is obvious that if reservoirs of equal size could be constructed in either of two watersheds at approximately the same cost, including cost of bringing the water to the distribution system, that watershed having the least erosion and sources of pollution should be chosen. Although water supply studies in recent years have generally given much weight to the factor of pollution, they have seldom evaluated adequately the problems created by the sediment load of the streams. Two types of damage arise from this sediment load, namely, the loss of reservoir storage capacity and the increased cost of water treatment.

In a recent study of the effects of soil erosion on the costs of public water supply in the North Carolina Piedmont section, Garin and Forster (3) have estimated the annual capital loss in 22 municipal reservoirs, resulting from the lost utility value by silting, at $32,000. The present worth of this sum, at rates of interest of $4\frac{1}{2}$ to 6 per cent being paid on the bonds issued for these developments, is $580,000. It might be argued that any sum up to this amount could be spent for the prevention of silting alone. Taking the municipal reservoir at High Point, N. C., as a typical example, these economists computed an annual capital loss of $5,224 based on a measured annual storage depletion of 0.77 per cent, a moderate figure for this region.

In addition, these two investigators found an increase in the cost of water treatment with increased sediment load. The average cost of treatment, including overhead charges and amortization of plant and equipment, is about $70 per million gallons. For treatment alone, the cost is $27, of which $5 is for cost of chemicals. The relation of the consumption of alum, which accounts for the greater part of chemical cost, to turbidity is shown in Fig. 7. They have estimated that reduction in the suspended load of the streams by 30 per cent, a modest expectation from an adequate erosion control program, would result in an average saving of $1.50 per million gallons in the cost of treatment, and that other savings resulting from smaller capital outlay for settling basins and filter plants, and from reduced costs of flushing and other plant operations would eventually bring

total savings to $7 per million gallons, or $94,500 annually for all towns in the North Carolina Piedmont area that have impounding reservoirs. Capitalized at 5 per cent, the present value of a 30 per cent smaller sediment load would be $1,890,000. These figures argue for both proper consideration of watershed characteristics in selecting the site of a reservoir and for erosion control on the watersheds of existing reservoirs.

A second aspect of location and design is the development of a favorable ratio between the capacity of the reservoir and the size of its tributary drainage area. This relationship is one of the most im-

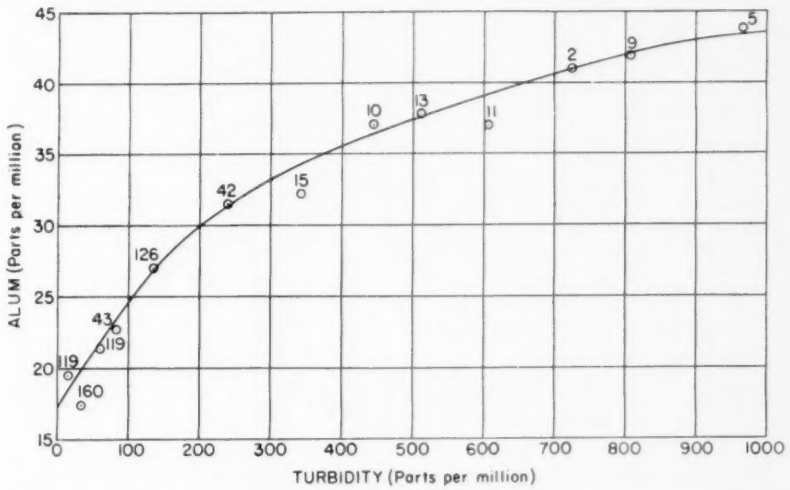

FIG. 7. Relation of Turbidity to Alum Use in Piedmont Section of North Carolina; showing composite curve (674 cases) for 12 representative filter plants

portant factors governing the annual rate of storage depletion. Table 1 shows that the average rate of silting of representative reservoirs in the eastern states increases as the average storage capacity per square mile of drainage area decreases. These data indicate that the average reservoir should hold at least 75 acre-feet of water per square mile in order to have a safe life of 100 years (assuming the useful life terminates with a loss of 80 per cent of the original storage). The significant fact that only 34 per cent of these representative eastern reservoirs have a ratio this high leads to the conclusion, from the standpoint of silting, that either the reservoirs are too small,

or the watersheds are too large. Study of the operating histories of the reservoirs reveals that a majority lost water by spillway discharge during 6 to 10 months or more in most years, and were seldom drawn down more than a few feet below spillway level. It is, therefore, apparent that smaller watersheds, in general, would have produced an ample water supply.

As a third consideration, adequate attention should be given in the design to the number, location, size, and manner of control of openings in the dam through which water can be released. The reason for this is explained below.

Lastly, reservoir basins developed off the main channels and supplied by water diversion have lower silting rates than reservoirs of corresponding size on the main stream, because diversion can be

TABLE 1

Relation of Original Storage per Square Mile of Drainage Area to Average Annual Depletion of Storage in the Eastern States

ORIGINAL STORAGE PER SQUARE MILE OF DRAINAGE AREA	NUMBER OF RESERVOIRS	PER CENT OF TOTAL NUMBER	AVERAGE ANNUAL DEPLETION OF STORAGE
acre-ft.		%	%
1–25	10	24	2.77
26–50	8	20	1.09
51–75	9	22	0.87
76–200	7	17	0.39
Over 200	7	17	0.28
Totals.....	41	100	

controlled to permit only normal stream flow to enter the reservoir and to bypass heavily sediment-laden flood flows downstream. Where topographic conditions permit, and this will not be in a majority of cases, the development of off-channel reservoirs should be seriously considered, even though higher costs per unit of storage are involved.

Water Release at Dams

The second approach to silting control is through improved practice in water release at the dam. Considerable data have been collected in the last five years, by field observations and laboratory experiments, on the movement of the finer particles of the sediment load of a stream through a reservoir. These studies have revealed the widespread occurrence of density currents or underflows of heavily

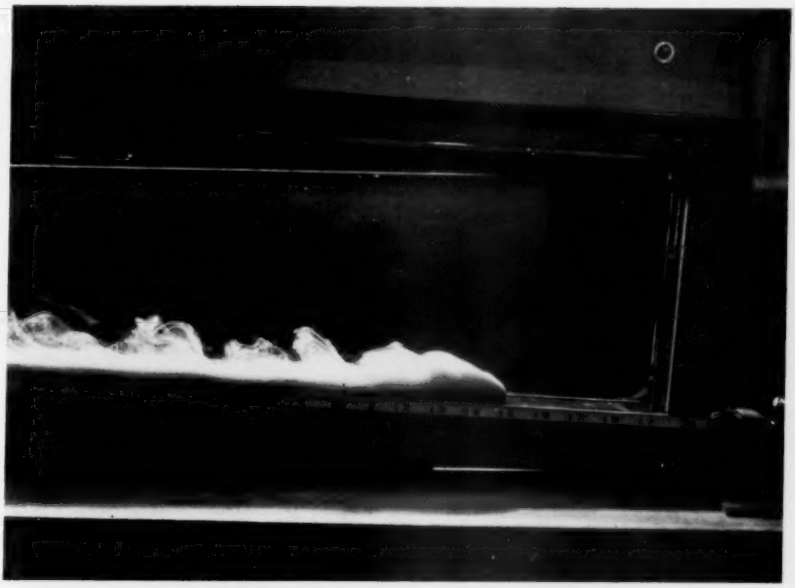

FIG. 8. Underflow of Silt-Laden Water in Experiment Tank Simulating Reservoir; slope of floor, 4 per cent; velocity of sediment front, 0.055 ft./sec.; density difference between flow and water in tank, 0.0035

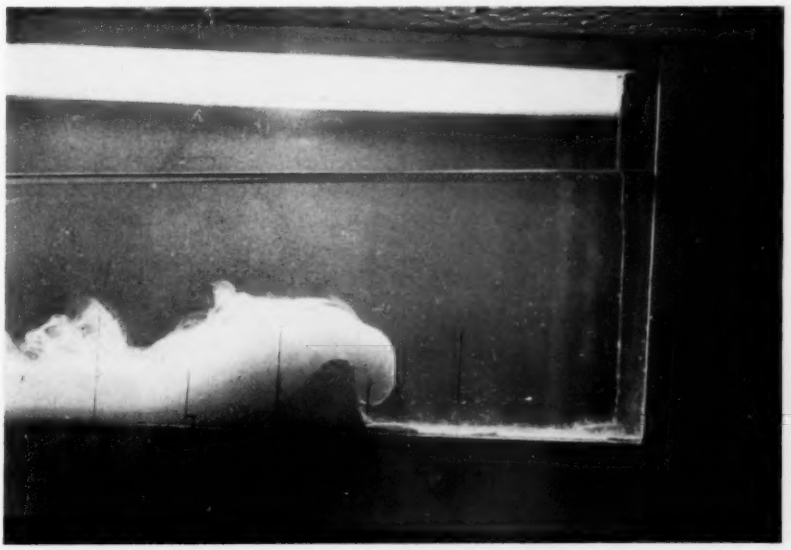

FIG. 9. Underflow Current Riding over Submerged Coffer-Dam in Experiment Tank

sediment-laden waters from the upper end of a reservoir to, and where possible through, the dam. Such currents are caused by the tendency of sediment-laden waters entering a reservoir to sink and move along the bottom under the relatively clear water already in storage. The underflow current is commonly characterized by differences in temperature and dissolved matter as well as by sediment content and can be readily recognized through sampling procedures. First observed and more carefully studied in some of the large western reservoirs (4, 5), underflow is known to occur, and may be common in all sections of the country. Occurrences have been reported in Lake Lee at Monroe, N. C.; Lake Murray, near Columbia, S. C.;

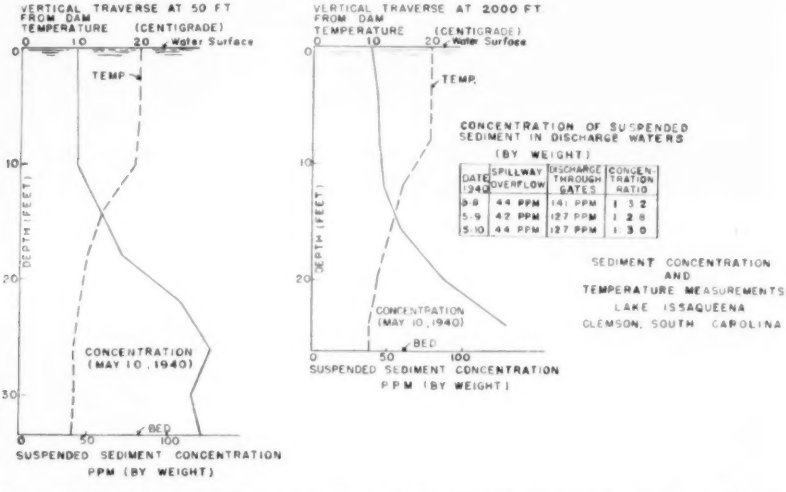
VERTICAL TRAVERSE AT 50 FT FROM DAM
TEMPERATURE (CENTIGRADE)
0 10 20
Water Surface
TEMP.
DEPTH (FEET)
CONCENTRATION (MAY 10, 1940)
BED
0 50 100
SUSPENDED SEDIMENT CONCENTRATION PPM (BY WEIGHT)
VERTICAL TRAVERSE AT 2000 FT FROM DAM
TEMPERATURE (CENTIGRADE)
0 10 20
Water Surface
TEMP.
DEPTH (FEET)
CONCENTRATION (MAY 10, 1940)
BED
0 50 100
SUSPENDED SEDIMENT CONCENTRATION PPM (BY WEIGHT)
CONCENTRATION OF SUSPENDED SEDIMENT IN DISCHARGE WATERS (BY WEIGHT)
DATE 1940 | SPILLWAY OVERFLOW | DISCHARGE THROUGH GATES | CONCENTRATION RATIO
5-8 | 44 PPM | 141 PPM | 1 3 2
5-9 | 42 PPM | 127 PPM | 1 2 6
5-10 | 44 PPM | 127 PPM | 1 3 0
SEDIMENT CONCENTRATION AND TEMPERATURE MEASUREMENTS
LAKE ISSAQUEENA
CLEMSON, SOUTH CAROLINA

FIG. 10. Relation of Temperature and Sediment Concentration to Water Depth in Lake Issaqueena, Clemson, S. C.

Lake Issaqueena near Clemson, S. C.; Norris Reservoir in Tennessee; Lake Dallas, Tex.; and in Leesville Reservoir, Leesville, Ohio. Lake Issaqueena, although constructed primarily for recreational purposes, is typical in size and other characteristics of the average water supply reservoir of the Southeast.

Measurements were made in 1940 of temperature and sediment content at two locations in this lake and samples were taken of the spillway overflow and discharge through a gate in the bottom of the dam. Figure 10 presents the results of part of these measurements which indicate that higher sediment concentrations existed in the lower levels of the lake at the time of sampling and that, on an average,

three times as much sediment was carried past the dam by water released through the bottom gate as in the water passing over the spillway. Moreover, these data show only the residual effects of density currents, as no actual flows were in progress at the time of sampling. When such flows are under way, the difference in sediment concentration between water at the surface and at the bottom, even in reservoirs prevailingly turbid, would be very much larger. This residual effect, due to slow settlement of fine sediment, may last for days or weeks, and the same effect probably exists without density currents simply as a result of normal settlement of fine particles from a turbid inflow. There is much evidence pointing to the value of maintaining a sampling program to determine surface and bottom sediment concentrations at the dam in all water supply reservoirs. If suspended sediment distribution in a vertical direction at the dam is found to be similar to that at Lake Issaqueena, as much as possible of the waste water should be released through whatever outlets may exist near the bottom of the dam. Conversely, water taken from the reservoir for consumptive use should be withdrawn as closely to the surface of the lake as possible to obtain that water having the least turbidity and requiring the lowest cost of treatment, provided, of course, the turbidity of the surface water is not so low as to increase cost of treatment by certain filtration practices.

The percentage of the total incoming sediment load that might be vented from the reservoir through proper gate control will differ greatly, depending upon the mechanical composition of the incoming sediment, the size and shape of the reservoir as they influence the movement of water through it, and the type and location of gates available for water release. The problem should be carefully studied on all reservoirs where sediment is a factor. It should be borne in mind that the difficulty and cost of removing sediment from an impounding reservoir depends upon the extent to which the sediment has settled and compacted. Once the sediment has compacted to a degree represented by a weight of 35 to 50 pounds of dry material per cubic foot of deposit, the cost of desilting makes its removal economically infeasible in most cases.

Soil Erosion and Sediment Movement

The third major factor in silting control—the control of soil erosion and sediment movement on the drainage area—is likely to be the most useful to the largest number of water works operators, and is unquestionably the most enduring in its effects.

Two plans of action to obtain better control on the drainage area are open to the city or water company. The area might be purchased in its entirety, further use of the land prohibited or adequately restricted, and the most effective of all erosion control—complete revegetation with trees and grasses—carried out with the assistance, if required, of state and Federal conservation agencies. For immediate supplementary protection until vegetation becomes effective, small dams or sediment barriers may be useful. This plan not only leads to the minimum of sediment production, but also does most to inhibit pollution. Numerous cities in the North Atlantic States, for example, have long ago seen the wisdom of this course and a number of splendidly protected watersheds are now in existence. In some instances the cost of purchase and protection of the watershed has exceeded the cost of the reservoir itself, but has been considered fully justified as long-term insurance.

Unfortunately, the cost of complete watershed purchase in many areas has been prohibitive, and, until five years ago, cities in such areas were confronted with the losses involved in reservoir silting without having feasible means of effecting a control of the sources of sediment. Since 1936, however, a new avenue toward better watershed protection has been developing in the nation-wide Soil Conservation Districts' program.

By April, 1941, the legislatures of 41 states had enacted soil conservation district laws, and 469 districts, embracing more than 287 million acres of land, have been organized (see Fig. 11). These laws, differing from each other only slightly in their provisions, are enabling acts which *permit* farmers and landowners to organize soil conservation districts, having the status of governmental subdivisions of the state, to engage in co-operative action to promote soil and water conservation and to prevent local or occasional misuse of land by voting land use regulations upon themselves.

The procedure for the organization of soil conservation districts is strictly democratic from beginning to end. A petition signed by a specified number of farmers and landowners, which can include municipalities and corporations, is sent to the State Soil Conservation Committee at the state college of agriculture. The state committee holds a public hearing. If a genuine desire and need for a district is manifested, the committee defines the proposed district boundaries and gives notice of a referendum to determine the sentiment of all persons within the prescribed area qualified under the Districts' law to vote on the issue. If the proposed formation of the district is

voted upon favorably, the state committee appoints two supervisors who obtain a legal certificate of organization and set a date for the election of three additional supervisors from among the voters in the district. When the board of supervisors is thus duly organized, it may consider and approve plans for erosion control activities, may enter into co-operative agreement with Federal and state agencies, accept technical services, allotments of funds and labor, and may purchase erosion control machinery, equipment, and materials such as seed, lime, or fencing.

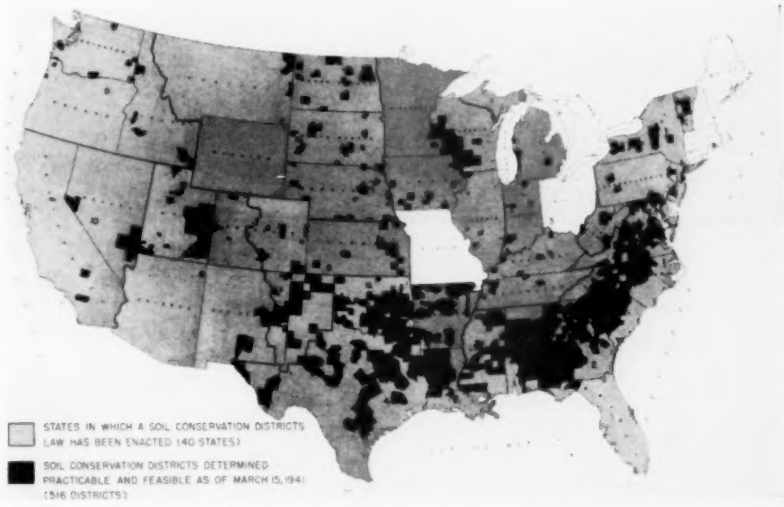
STATES IN WHICH A SOIL CONSERVATION DISTRICTS LAW HAS BEEN ENACTED (40 STATES)
SOIL CONSERVATION DISTRICTS DETERMINED PRACTICABLE AND FEASIBLE AS OF MARCH 15, 1941 (516 DISTRICTS)

FIG. 11. Status of Organization of U. S. Soil Conservation Districts to March 15, 1941

In several States, plans are now materializing for the co-operation of certain towns and cities that own municipal reservoirs with organized districts in the development of erosion control programs designed to effect the largest practicable degree of sediment reduction in the streams supplying the reservoirs.

Among the conservation practices most widely recommended for erosion control are: (1) proper crop rotations; (2) plowing on the contour; (3) terracing; (4) strip cropping; (5) development of vegetated field drainage ways; (6) check dams; (7) reforestation and fire protection; and (8) grazing control.

These measures are applied mainly to the usable—the productive—land of the farm unit. There are other sources of sediment in many

FIG. 12. Severe Gullying near Bethany, Mo.; large amounts of sediment have entered streams from this area

FIG. 13. Gullied Area after Construction of Dam and Protection of Lake by Vegetation; all of area above dam will contribute no sediment to downstream reservoirs for many years and regulation of flow will reduce gully-cutting below dam

FIG. 14. Bank Erosion on Winooski River, Chittenden County, Vt.; showing area of bank severely eroded by 1936 flood—erosion which produced large amounts of sediment affecting reservoirs

FIG. 15. Same Area on Winooski River 2 Years Later; showing effects of protection by willows

watersheds, however, which are often extremely hazardous to the downstream reservoir, but perhaps less dangerous to the individual farmer. These sources are erosion on stream banks, erosion of the ditches and fills of roads and railroads, gully erosion on land abandoned or unproductive for agriculture, and industrial wastes, especially from coal mining. The treatment of these sources is sometimes expensive, and the individual farmer may be economically incapable of controlling them even if he feels justified in doing so, but the co-operation between farmer and municipality or water company often can accomplish, to mutual benefit, that which either one alone could not undertake.

It seems particularly appropriate, therefore, that water supply interests, where they are confronted either with significant reservoir silting or excessive filtering costs, should be concerned with developing co-operative relations with soil conservation districts while these organizations are still in their formative stage. If districts are not yet organized in any particular area, the county agricultural agent, the state director of extension, or the state co-ordinator of the Soil Conservation Service at the state college of agriculture will be glad to outline ways in which the water supply interests might assist in developing such districts and in co-operating with them. It may be anticipated that in many areas the addition of services and materials by the city or water company to the resources of the farmer would achieve a degree of erosion control and watershed protection not only of direct benefit in excess of cost to the city, but of even greater indirect benefit through increasing farm income and hence buying power of the community.

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Financial Considerations of Distribution System Extensions

By F. R. Berry

BEGINNING about 1930 there was a reversal in the population trend. For a number of years prior to that date there had been a marked increase in the movement of population to urban areas. The development of inexpensive automobiles was a major factor in a chain of events which slackened noticeably the growth of the cities and brought about corresponding increase in the population of suburban or rural areas. This change, continuing up to the present time and probably due to continue for an indefinite future period, has presented a difficult problem to the operators of water works properties. The supplying of water to closely built-up areas has necessitated a minimum investment in distribution facilities. Records over the past ten years indicate a substantial decrease in saturation, i.e., in the number of customers per mile of distribution main.

The extension of distribution system pipe lines into the outlying areas, where the saturation is low, necessarily results in a higher investment in distribution facilities per customer or per dollar of operating revenue. This has already adversely affected the rate of return being received by certain water companies to such an extent that an increase in rates has been found necessary to provide a fair return on the fair value of the property.

The owners of property in the rural areas generally have less investment in real estate, and also pay lower taxes because they do not get municipal service equal to that obtainable in the cities. Police and fire department protection are two types of service which, in general, are not provided. For a water company to serve these suburban customers, long extensions with low saturation are frequently

A paper presented on April 25, 1941, at the Indiana Section Meeting, Indianapolis, Ind., by F. R. Berry, Engineer, American Water Works and Electric Co., New York City.

necessary. If these are made solely at the expense of the utility, and if the rates are like those for service within the municipalities, the closely built-up areas will, eventually, be penalized, the benefits accruing to the outlying areas since the various regulatory bodies, in prescribing rates for a water utility, usually set uniform rates for like classes of service in the entire area served by one water company.

The interests of the present customers of a water utility should, as far as possible, be given consideration and be protected by a water utility when extensions of its distribution system to sparsely settled outlying areas are to be made. It is eminently unfair to penalize customers within the closely built-up areas for the benefit of those in the outlying areas who do not have a comparable property investment and whose taxes are generally lower.

The author, here, proposes to discuss the factors to be considered when the question of extensions to outlying areas is up for final decision, the idea being that such extensions should, in general, carry their proper proportion of the cost of service.

Effect of Extensions on Operating Expenses

If extensions to the distribution system could be considered as a subject completely divorced from that of the system as a whole, there would be no problem, but a pipe line laid along a highway with the necessary service lines and meters installed is of no value in rendering water service unless it is connected to the existing system which, in turn, is connected to the source of supply. In considering extensions, then, this relationship must be taken into account. Primarily, two factors—the increase in operating expenses and the investment necessary to furnish the service—are to be given consideration in planning extended service.

The increase in operating expenses should be looked at over a long period, and not on the basis of the immediate out-of-pocket cost. As an example, the number of employees at a pumping station would not be increased by the addition of only a few customers, but when considered over a long period, additional pumps and additional pump operators would no doubt, be necessary. The same line of reasoning applies to items too numerous to enumerate. It has been the author's experience that the most satisfactory way to determine the effect on operating expenses of a water company resulting from the addition of new customers is to consider the operating ratio over a reasonable period.

To determine this long time effect, of course, a study of past records and experience is desirable. Such studies of a number of water utilities have been made by the author to determine whether any reasonably uniform relation existed between operating expenses and operating revenues. The companies selected for the studies were widely scattered and there was no uniformity in operating conditions, some being static and some expanding rapidly, the purpose of such choice being to get a wide diversity in operating conditions, locations and rates of growth. In each case the study covered a ten-year period, during which there had been no change in the rate schedules, and no material change in operating conditions or price levels.

Operating Ratio

In each year for each company the operating ratio, i.e., the percentage of gross operating revenues expended or set aside for operating expenses and depreciation, was calculated. In the particular studies, taxes and depreciation were not included in operating expenses as these items are subject to wide variations and fluctuations and are generally beyond the control of the company.

An analysis of the studies made showed clearly that there was a direct relation between such operating expenses and operating revenues. The operating ratios were relatively uniform for each company; the fluctuations were minor or explainable. This was true in each case, regardless of the location or size of the property or whether static or expanding rapidly; and on that basis it has been possible to conclude that, in determining additional operating expenses likely to result from extensions to the distribution lines and the addition of customers, the operating ratios should be applied to the estimated additional annual revenue to determine the amount available for return.

The previous remarks have been made only to show that over an extended period the operating ratio, considering direct operating expenses, exclusive of taxes and the annual allowance for depreciation, will remain practically uniform. In determining the operating ratio to be applied to the estimated additional operating revenue, taxes and the allowance for depreciation should, of course, be included in operating expenses; and, except in unusual cases, the last available operating ratio should be used.

Obviously, there will be no uniformity in the operating ratio, as operating conditions and other factors vary materially. One com-

pany's operating expenses may be high because it employs softening. The terrain may be such that high pressures have to be carried. Each company, therefore, should calculate its own operating ratio, which, of course, will reflect the particular operating conditions present.

Investment Requirements of Extensions

The second factor to be considered in determining whether a water utility would be justified in making extensions to its distribution system to supply customers applying for service is not only the immediate investment required, but also the prospective investment.

The immediate investment will be the cost of the extension to the distribution system, a service line and probably a meter for each anticipated customer, and the cost of fire hydrants and fire hydrant branches, if fire service is to be furnished. These costs, however, are only part of the total; behind them are many items which are also essential—pumping stations, purification systems, transmission pipe lines, distribution reservoirs, impounding reservoirs, dams, real estate, etc. It is obvious that a proper proportion of these and other items, referred to as supply facilities, must be considered as part of the capital investment necessary to render the service, or a water company will, at some time, inevitably be faced with the necessity of securing an increase in its rates or be unable to meet its financial obligations.

It has been argued that the investment in supply facilities has already been made and that no additional investment is necessary. This is a very short-sighted view and takes into consideration only the present and immediate future. A water company must, in fairness to its present customers, take a long range view and recognize the fact that there will come a time when additional supply facilities must be added. Water works plants cannot be built in increments for one customer. If plants could be built in such a way, it would be necessary only to add to the cost of the distribution facilities the cost of the necessary supply increments to arrive at a total investment necessary to supply the new customers.

Investment Ratio

In considering the necessary investment, both immediate and prospective, on which a return should be earned, however, a ratio must again be used—in this case the ratio of the value of the distribution system to the value of the property as a whole. To determine

such a ratio, it is necessary to have a reasonably accurate record of the value of the various component parts of the water works system. For convenience, the distribution system facilities may be taken to include only the pipe lines, fire hydrants and fire hydrant connections, and the supply facilities all other parts of the property.

As an example, a hypothetical plant may be assumed to have component parts valued as follows:

Dams and reservoirs	$250,000
Transmission mains	150,000
Purification system	80,000
Pumping station and equipment	60,000
Distribution reservoirs and tanks	25,000
Service pipe lines	80,000
Meters and boxes	60,000
General equipment	10,000
Fire hydrants	15,000
Distribution pipe lines	750,000
Total	$1,480,000

The value of distribution pipe lines, fire hydrants, and hydrant branches in this system is $765,000, or 51.7 per cent of the total. This means that for every $1,000 of value on the hypothetical system, $517 is the value of the pipe lines, hydrants and hydrant branches, i.e., distribution facilities, and $483, the value of all other parts, i.e., supply works. A close association with many water works plants over a long period of time has shown that such a proportion of supply facilities and distribution facilities does not change materially as long as the method of supplying water remains the same, though there will, of course, be ups and downs of minor proportions.

Again, supply facilities cannot be installed in increments for one customer, and when it becomes necessary to increase the supply facilities, as, for instance, increasing the capacity of the purification works, the installation of additional pumping equipment, the construction of an additional storage reservoir, or other items too numerous to mention, the supply facilities will be a larger proportion of the total than immediately prior to such installation. If a curve were drawn over a long period to show the proportion of the value of the supply facilities to the total value, it would resemble a saw-tooth curve, the high points following immediately the additions to the supply facilities, and the low points just prior to the installation of such additional facilities, but the general trend would be a constant.

In this connection the author has a record of the capital expenditures, for the year 1940, of about 80 water works plants. The total amount involved is almost $4,000,000, of which 52.7 per cent was spent for distribution mains, hydrants and hydrant branches. This percentage remains approximately the same year after year and is also approximately the same as the ratio of distribution facilities determined from studies of the value of many water works systems. Any water works company which, in considering extensions to its distribution facilities, neglects to give proper recognition to the fact that there will be a necessary investment in supply facilities, fails grossly in its duty and will eventually face the necessity of increasing its rates or going into receivership.

Determination of Soundness of Investment

Having shown that there is a direct relation between operating expenses and operating revenues, and also that consideration must be given not only to immediate investment, but also to prospective investment in supply works, it is proposed now to demonstrate how to determine whether the prospective revenue from a given extension is ample to justify its installation at the sole expense of the water company and what investment would be justified for a given amount of additional operating revenue.

First, a percentage figure to be applied to the estimated cost of extensions to the distribution system is determined and this amount compared with the prospective additional revenue, to determine its adequacy. The formula for such determination is:

$$R = \frac{a}{bc}$$

where R is the value, in per cent, to be applied to the estimated cost of distribution facilities; a is the assumed rate of return; b is the per cent of additional operating revenue available for return; and c is the per cent of total system value in distribution facilities. Then a multiplier which can be applied to the additional operating revenue to show the investment which would be justified is developed, the formula being:

$$M = \frac{100}{R}$$

where M is the multiplier to be applied to additional operating revenue and R is the value determined in the previous formula.

The previous hypothetical example may then be carried a little further by applying both these formulas. Assuming that the company has an operating ratio of 54 per cent, i.e., that 54 per cent of the gross operating revenues are necessary for all items of operating expenses which are to be deducted from the gross operating revenues in arriving at the amount available for return, leaving 46 per cent of the operating revenues available for return, and assuming that the rate of return should be 6 per cent, with distribution facilities at 51.7 per cent of the total value, application of the first formula would be as follows:

$$R = \frac{.06}{.46 \times .517} = 25.2$$

This means that if the additional operating earnings amount to less than 25.2 per cent of the estimated cost of the additional supply facilities, the water company, at its sole expense, would not be justified in making the necessary investment.

Applying the second formula, the result would be:

$$M = \frac{100}{25.2} = 3.9$$

This means that a water company would be justified in investing in additional distribution facilities up to 3.9 times the additional operating revenue.

Another method to determine the amount which a water company would be justified in investing in additions to its distribution facilities is to calculate the amount of money which such water company has invested in distribution facilities per dollar of operating revenue from presently attached customers and multiplying this amount by the additional operating revenue to be obtained from such extension to obtain the maximum justified investment. This method assumed that a water company can afford to invest the same amount in extensions to its distribution facilities for each dollar of new revenue as it has invested in like facilities for each dollar of present revenue. It gives substantially the same answer as the first method if the rate of return being earned is the same as the assumed rate, but has the advantage of being easier to explain. The first method provides a proper return which, in the hypothetical case was 6 per cent. The second method provides the same return on extensions as is being obtained on existing facilities.

Protection of Existing Customers

These are the proper factors to be taken into consideration in determining the advisability of making extensions to a distribution system and the amount of money which a water company would be justified in investing for a given amount of additional earnings. Water companies have, during recent years, been flooded with requests for unprofitable extensions of their distribution systems, caused, to a large extent, by the present population trend away from the centers of population to the outlying areas. In studying such requests it is the duty of a water company to give due weight to the probable ultimate effect of extension on its existing customers. The continued installation of unprofitable extensions to the distribution system of a water works which is barely earning its fair rate of return will soon necessitate an increase in rates, and this increase in rates will probably apply to existing customers, as well as to new ones, thereby imposing upon the existing customers the necessity for paying charges for water service which are out of line with the cost of serving them and giving the benefit of the increased revenue to the outlying districts where people have moved, often with the idea of effecting savings in investment in real estate and savings in taxes.

If a water company were assured that it would receive a fair return on the fair value of its property, regardless of where it laid extensions, whether they were profitable or unprofitable, the company could not properly object to the installation of long, unprofitable extensions. Such a condition cannot, of course, exist because the rates of a water company cannot be adjusted every year to compensate for unprofitable and injudicious investments. It is obvious, then, that in advocating a reasonable basis for extensions to a distribution system, a company is protecting the interests of its existing customers.

New Jersey Regulation of Extensions

In New Jersey and New York regulatory bodies have promulgated general rules relating to extensions to water company distribution systems. In New Jersey, general rules, adopted on January 2, 1923, give two methods for extensions to the distribution system. One, Plan B, provides for a guaranteed monthly revenue on the basis that the entire cost of the extension shall be borne by the water company and that the guaranteed amount is equivalent to an annual return of approximately 28.6 per cent on the cost of the pipe. The

other, Plan A, provides that the water company may pay only part of the cost of the extension, and that the real estate developer or other party deposit the remainder with the company. This rule provides that in the event the cost of the extension does not exceed $3\frac{1}{2}$ times the estimated normal yearly charge for service at regular rates, including the proper amount for fire service, the water utility shall make the extension at its cost and expense. It further provides that where the cost of the extension exceeds $3\frac{1}{2}$ times such estimated revenue, the company shall pay towards the cost of such extension $3\frac{1}{2}$ times such normal yearly estimated revenue, the applicant to pay the remainder. Such payments are to be refunded to the applicant as additional customers are connected to the extension to the extent of $3\frac{1}{2}$ times the annual revenue from such additional customers until the amount deposited has been repaid without interest, provided, however, that no repayments are to be made after a period of ten years.

Both of these plans were promulgated when a reasonable rate of return for water utilities was considered to be not less than 7 per cent and probably were based on the assumption that the operating ratio was 50 per cent. Under these conditions a return of 28 per cent would be equivalent to a 7 per cent return on the cost of the extension and a proper proportion of the supply works, and $3\frac{1}{2}$ times the annual revenue is equivalent to approximately 28.5 per cent.

Experience in connection with the operation of a number of water works plants in New Jersey, where these rules have been used, has indicated that there have been no complaints before the state regulatory body requesting that the water companies be required to make extensions. It is recognized by every one concerned that the rules are to be adhered to by the water company and accepted by applicants. The existence of such a rule is to the definite advantage of a regulatory body in the practical elimination of complaints from this source. Such a rule is also to the definite advantage of existing customers as it protects their interests and assures a reasonable return from extensions which might otherwise be a burden and eventually necessitate an increase in the rate schedule.

New York Regulation of Extensions

On April 30, 1940, the Public Service Commission of the State of New York adopted rules which relate to the installation of mains. In general, these rules provide that a water company shall extend

its mains, for any prospective customers, for a distance not to exceed 75 ft., such extension to be made by, and at the expense of, the company. The rules further provide that, for extensions of more than 75 ft., such extension shall be made by, and at the expense of, the company, but that the applicant for such extension shall agree to pay the water company, in addition to its regular rates, a surcharge of 9 per cent on the reasonable cost of that portion of the extension which is in excess of 75 ft. This rule is based on the extension of mains 6 in. in diameter or less. If the company elects to extend a larger size main, the applicant shall pay in addition to the regular rates, 9 per cent on the estimated cost of a 6-inch main. The rule states that this 9 per cent is to cover return, depreciation, taxes and maintenance.

An interesting part of the New York rule is the provision for the adjustment of the surcharge when additional customers connect to the extension. It provides that when the number of customers multiplied by 75 ft. equals or exceeds the length of the main extension, no further surcharge shall be paid and, further, that whenever the total revenue in one year from all customers on the main extension shall exceed one-quarter of the actual reasonable cost of the extension, provided it be 6 in. or less in diameter, no further charge shall be made. Based on this provision, the New York commission must, by inference, have assumed that the average water company would earn from an average customer 25 per cent on the cost of 75 ft. of pipe line. In adopting such a rule the New York commission recognized the fact that a water company was entitled to consider investment in supply works as part of the necessary total investment in rendering service, or the rate would have been substantially less than 25 per cent.

Effect of State Regulation

In the author's analysis, both states, in these rules, have given definite recognition to the fact that a water company is entitled to earn substantially more than a return on the immediate out-of-pocket investment and the possible additional increment operating expenses. The New York rule requires the water company to provide all of the necessary funds for extensions to distribution systems, and if it is assumed that the revenue to be obtained from an average customer will pay a return of 25 per cent on the average cost of 75 ft. of pipe, provision is made, after allowing for additional operating expenses,

for return on the cost of 75 ft. of pipe and the proper proportion of the supply works to supply one customer. The rule further provides a surcharge for return, depreciation, taxes and maintenance on the cost of any length in excess of 75 ft., where obviously no part of the supply works is needed. It does not, however, give any consideration to the fact that conditions may vary materially at different locations and result in substantially different costs of pipe line installations. The New Jersey plans, on the other hand, refer definitely to the cost of the extension, and, therefore, do give proper consideration to any difference in the cost of pipe line installations. It is obvious that the installation cost of a pipe line would be substantially higher at some locations where rock is prevalent than where easy excavation prevailed.

The interesting fact, however, is that two regulatory bodies have given definite recognition to the need for adopting rules which, in effect, give protection to existing customers. It is the author's opinion that regulatory bodies of other states having jurisdiction over extensions to a water company's distribution system will recognize the fact that definite rules are desirable. Such definite rules should either prescribe a method and allow each company to submit its own requirements, subject, of course, to the approval of the regulatory body, or prescribe rules of such a general nature that the interests of existing customers will be protected in order to avoid the necessity for rate adjustments which will, in effect, penalize existing customers for the benefit of those residing in sparsely settled areas.

Special Considerations in Static Systems

Up to this point, these remarks have applied to water works plants enjoying a normal rate of growth and where periodic additions to the supply works are necessary. There are some water works systems, however, which do not come within this category. These are communities which are static, where the capacities of the supply works are such that many additional customers can be added without the need for additional supply works. Companies of this type should receive special consideration. The capacity of the supply works, as related to the demand, should be known and recognized, and where there exists surplus supply works capacity, the treatment of requests for extensions to distribution systems should recognize this fact.

In such cases the rate of return as applied to the distribution pipe only can be substantially less than where normal growth is being enjoyed. The operating ratio will not change materially at such plants, so the operating ratio should be applied to the estimated additional revenue to determine the amount available for return; and if this amount will produce a reasonable return on the cost of the additional facilities, including pipe line extensions, meters and services, such extensions should receive favorable consideration.

In conclusion, it should be reiterated that regulatory bodies should recognize the need for protecting the interests of existing customers, and that they will best serve the interests of water companies and their customers if they prescribe rules requiring each company to submit for approval its general requirements for extensions.

Costs of Distribution System Extensions Beyond Corporate Limits in Northern Indiana

By E. D. Anderson

SEVERAL factors involved in the extension of utility facilities into areas beyond the corporate limits of municipalities have caused a serious problem to utility companies, especially in recent months. Requests for utility service into such outlying areas have been caused largely by the growth of such areas due to accompanying industrial growth in the community, to the desire of people to obtain lower cost of real estate, and to the lower taxes prevailing in these areas; and, although many people are moving out of urban areas for these reasons, they still demand metropolitan service there despite the fact that, in many cases, permanent street grades, sewers and street improvements are not yet available. These factors have, of course, placed the utilities in an embarrassing position.

In this same connection, similar problems have been created in a number of cases where municipalities have annexed sparsely occupied territory in a race with other municipalities to maintain their municipal growth and stability. This has been especially true in certain areas in northern Indiana, close to the industrial centers south of Lake Michigan. The experience described here will refer principally to a case of this latter type in which the Northern Indiana Public Service Co. was involved.

In 1938, the Common Council of Hobart, Ind., passed an ordinance ordering the company to build approximately six miles of mains into two of these areas. The town has a population of 5,800 and an area of approximately $8\frac{1}{2}$ sq.mi., much of which has been expanded recently to take in several large sparsely settled areas. The ordinance ordered that water be provided to two annexed areas through

A paper presented on April 25, 1941, at the Indiana Section Meeting, Indianapolis, Ind., by E. D. Anderson, Vice-President, Northern Indiana Public Service Co., Hammond, Ind.

extensions of service, the total cost of which would have been approximately $48,000. In the areas there were only 173 prospective customers, of which 158 were residential consumers whose estimated annual contributions to revenue, at prevailing rates, would be $13.13 each, obviously insufficient to justify the extensions.

The company fully realized its responsibility to provide utility service in any new areas, but it felt that extensions could be made only on the basis of sound economics weighed against the factors of possible growth of service and customer good will. Present utility management, must, of course, recognize a three-fold responsibility in all of its action—to its customers, to its employees and to its investors or owners. It was necessary, then, because of the unreason-

TABLE 1

Details of Co-operative Plan to Finance Extension

Estimated cost	$13,219.00
Revenue per customer (5 yr.)	90.00
Contribution per unit	75.00
Revenue 46 customers (5 yr.)	4,140.00
Revenue 3 hydrants (5 yr.)	862.00
Cash 50 units	3,750.00
Total	8,752.00
Deficiency	4,467.00
Houses facing line	61
Agreeing to take service	46*
Units agreed	50†

* Now 50. † Now 54.

ableness of the request, to appeal the ordinance to the Public Service Commission of Indiana, asking that it be set aside. After hearings and presentation of evidence in the spring of 1938, the Commission held that the ordinance was void and unreasonable.

New Extension Plan

Some time later, on June 5, 1940, the Common Council of the city passed another ordinance ordering the company to install mains into the smaller of the two areas. It may be wondered why the Council would proceed on this basis after the petition on the two extensions had been held unreasonable, but it must be remembered that councilmen, too, have their problems and responsibilities. Considerable

pressure from residents in the new area was placed on the Council because many of the private wells were dry and those from which water could be obtained were badly contaminated. To remedy this situation, the particular extension, for which the second ordinance was passed, called for the installation of 7,300 ft. of mains, together with laterals, three fire hydrants, meters, and services, the estimated cost of which was $13,219.

The company, realizing the serious problem confronting these people, held several meetings with a committee of the residents and was able to work out a plan (Table 1) whereby service could be extended to the prospective customers, the company assuming a substantial part of the investment cost and the customer supplying a pro-

TABLE 2

Units Installed—Estimated and Actual

ITEM	ESTIMATED	ACTUAL	DIFFERENCE
Pipe:			
6-inch	3,343 ft.	3,332 ft.	−11 ft.
4-inch	1,325 ft.	1,374 ft.	+49 ft.
2-inch	2,415 ft.	2,584 ft.	+169 ft.
Total	7,083 ft.	7,290 ft.	+207 ft.
Hydrants	3 pc.	3 pc.	—
Services:	48 pc.	48 pc.	—
Pipe			
¾-inch	1,050 ft.	1,363 ft.	+313 ft.
1-inch	—	48 ft.	+48 ft.
Total	1,050 ft.	1,411 ft.	+361 ft.

portionate share of the cost with certain refunding participating rights in the line over a period of development.

The monthly minimum of the rate under which service is supplied in the community is $1.00 per month. It was necessary, however, to make arrangements whereby the customers would pay the company a minimum of $1.50 per month during the period of development or until 235 customers were connected to the facilities. The plan worked out and filed with the Public Service Commission of Indiana included the following items:

1. Specific description of the original extension.

2. Conditions of service, including cost of the tap fee, customers' duties in regard to the part of the cost to be furnished by them.

3. Metering.

4. Charge to customer if turned off for non-payment of service bill.

5. Contribution by the customer of $75.00 to be paid in twenty payments of $3.75 per month.

6. Company's obligation to refund to customers as additional business was secured.

7. Rate to be charged for water service.

8. Minimum monthly payment.

TABLE 3

Installation Costs—Estimated and Actual

ITEM	ESTIMATED	ACTUAL	DIFFERENCE
Installation of Mains:			
Material	$4,995.00	$4,618.29	−$376.71
Labor	3,930.00	3,948.00*	+18.00
Stores	652.00	230.79	−421.21
Truck	640.00	23.18	−616.82
Digger	160.00	—	−160.00
Engine and Car	230.00	122.44*	−107.56
Overhead	1,590.00	1,311.79†	−278.21
Total Main Installation	12,197.00	10,254.49	−1,942.51
Installation of Meters and Services:			
Meters:			
Labor	371.00	371.00‡	
Material	412.80	412.80‡	
Services:			
Labor	806.00	309.19§	−496.81
Material	388.00	521.00¶	+133.00
Stores (12% of material)	96.00	112.05	+16.05
Overhead (15%)	301.00	258.90	−42.10
Total Meter and Service Installation	2,374.80	1,984.94	−389.86
Less: Tap Fee	240.00	240.00**	
Net Meter and Service Installation	2,134.80	1,744.94	−389.86
Total Installation	$14,331.80	$11,999.43	−$2,332.37

* Estimate of split of charges other than contract amount included.

† Includes 15% of unpaid balance of $848 still due contractor.

‡ No actual figures; assumed to be same as estimated.

§ Amount paid contractor for installing services.

¶ No actual figures; estimated cost increased in proportion to actual lengths installed.

** Tap fee for 48 customers, although only 30 have been connected.

A short form agreement was prepared for the customers to sign, this agreement referring to the plan which was filed with the Commission. In October, 1940, the required number of contracts under this plan had been obtained and work was completed early in 1941. Data on units installed and costs of installation are given in Tables 2 and 3.

Although the figures given in this discussion indicate that the extension is not particularly profitable, it must be realized that it has satisfied the customers involved, in solving their problem of water supply and fire protection, and has made some friends for the company. It seems that it is sound policy to take a reasonable gamble in areas such as this where there is a possibility of development. In all such cases, of course, the economic factors must also be weighed against the good will factors.

Insurance Requirements for Water Works Properties

By R. F. Goodhue

A PAPER on the insurance requirements of water works properties must necessarily begin with a review of the background of the standard grading schedule, in national use, sponsored by the National Board of Fire Underwriters, as it is upon this schedule that all such standards are based.

Analysis of fire protection by schedule grading had its real start in the investigation following the Baltimore conflagration of 1904. It was realized then that while there is a fairly even rhythm in loss experience on five- to ten-year cycles, this rhythm does not allow for the huge losses of major conflagrations. The insurance rate in any particular community cannot include the possible factor of conflagration since the increase in rates necessary to provide for that factor would render protection prohibitive in almost every case. The conflagration hazard can be handled only by nation-wide coverage and by the pooled resources of the insurance companies. One of the major purposes of schedule grading of fire protection is to uncover the possible sources of conflagration and to aid in their removal.

The schedule starts with an assumption of perfection in fire protection and grades down to existing conditions. Aptly called a yard stick, it measures the relative strength of fire protection in like communities. Since the standards are the result of compromise rather than of arbitrary opinion, it is a matter of pride that details are far from static. As this paper is written (November, 1940) a further revision is being prepared; and, as usual, this will embody the consensus of opinion of water work designers and operators, as well as of fire chiefs, fire alarm men, construction engineers, builders, and

A paper presented on November 8, 1940, at the Four States Section Meeting, Wilmington, Del., by R. F. Goodhue, Engineer, Middle Department Rating Association, Philadelphia.

experts in the field of combustible and explosive materials. In this way a sincere effort is made to keep the schedule progressive.

Schedule analysis of water for fire protection as well as of all other components of that protection must be built around the focal point of structural conditions. The first objective of fire protection as well as of the other components must be the development of sufficient strength to combat potential conflagration hazard, as indicated by existing structural conditions. These conditions dictate the quantity of water required, and that, in turn, suggests the fire department strength.

Empirical Formula for Probable Fire Demand

Probable fire demand by schedule starts with an empirical formula: $G = 1{,}020\sqrt{P} - (1 - .01\sqrt{P})$, in which G equals g.p.m. and P, population in thousands. The formula is merely a base, predicated upon the fact that the majority of American cities largely conform to type in structural features, in direct proportion to the population curve. The exceptions will include shore resorts with a basic population of possibly 5 per cent of the seasonal load, southern cities where large frame areas are normal, university cities with six to ten times the normal population base, and agricultural centers with huge warehouse and grain elevator development. Departure from the formula requires experience in judging combustibility and this is done as sincerely as experience and skill will allow.

This probable fire demand, which varies roughly as the square root of the population, starts at 500 g.p.m. and stops arbitrarily at 12,000 g.p.m., applied to distribution systems, and at 20,000 g.p.m. applied to supply works. Since this demand is the basis for the entire water supply analysis, the results are frequently checked against maximum fire conditions. Reference is made here to data on six conflagrations including Norfolk, Nashua, Fall River, Nashville, Salem and Chelsea, compiled by C. W. Mowry.* Averages show a fire duration of 8.75 hr., against the 10-hour standard set up in the schedule, a fire volume of 16.0 m.g.d., with peak use at a rate of 19.4 m.g.d. as against schedule demands of 11.1 m.g.d. Schedule fire demand is generally conceded by fire protection engineers to be conservative. Reliability of supply from the fire protection standpoint becomes relatively more important in the lower population brackets where domestic consumption is

* MOWRY, C. W. Water Consumption During Fires. Quarterly of the National Fire Protection Assn. **25:** 266 (1932).

overshadowed by the probable need for fire purposes. Assuming two communities with population extremes of 3,000 and 3,000,000, each with daily per capita consumption of 50 gal., the fire demand by schedule will vary from 1,000 g.p.m. for 5 hr. to 20,000 g.p.m. for 10 hr. The relation of fire demand to domestic consumption in the smaller community is 200 per cent, and in the larger, 8 per cent. Large communities, in providing for domestic demand, will almost automatically include the necessary quantity for fire protection, but smaller communities must increase their available supply to include the much larger factor of fire needs. This factor may be in raw water storage or more probably in elevated clear water. While there can be no tailor-made design for supply works, an attempt has always been made to work on the basis of economic feasibility. Nothing is achieved by insisting on perfection in water supply when the other factors of fire protection are imperfect. The basis of good fire protection is founded in the balanced strength of all its branches.

It is not the intent of the author to review the mathematics of the schedule. Copies are readily obtainable, and the rating bureau in whose underwriting jurisdiction any particular system lies will be glad to consult with water works men on any point in their grading of the supply. The National Board of Fire Underwriters, which acts in the capacity of consulting engineers to the local rating boards, is also at the service of the designer and operator. The purpose of this paper, rather, is to discuss the salient points in water supply which cause the greatest difficulty.

Hazards in Water Works Structures

In the inspection of many water systems it is a puzzling fact that, despite the essential and emergency character of water and the value of equipment in the supply works, buildings themselves are so often haphazardly constructed. It is quite common to find boiler rooms, transformers and switchboards, pump rooms and filter galleries under a single combustible roof, and 100 per cent subject to fire. It has often been found difficult to get the officials in charge to cut off these communications by the use of fire doors, even when credit is given in the basic grading, as well as in the insurance rate on the individual building, for such safeguards. It is not unusual among the smaller systems, with pumping stations isolated from the community proper, to find a lack of any provision—hydrants, standpipes or accessible suction supply—to fight fire in the combustible buildings themselves.

Very few water works structures are equipped with automatic sprinkler systems, although in most cases the filter wash water tank could be utilized readily as a prime source of supply for this purpose. Considering the long life expectancy of the typical supply structure, the amortization of capital costs necessary for fire-resistive construction becomes a minor factor. Such construction will pay dividends through the years in its effect upon the insurance rate of the buildings. The rating boards will be very glad to consult with any water works designer on construction of new units and the revamping of older stations. In this respect the value of the insurance engineer lies primarily in his different attitude toward the questions involved. Where the water works operator is working for economic maintenance and convenience of operation, the insurance engineer is necessarily critical, for it is his job to find the weak link in the sequence of operations. The compromise of these two attitudes of mind often produces notable results.

Elevated Storage Economy

It is not necessary to go too deeply into the economics of elevated storage. It is a factor which varies greatly with the characteristics of the individual system. The schedule states: "to have no deficiency, pumping capacity and storage must be able to provide fire flow for ten hours, over a period of five days maximum consumption." In the great number of small systems, utilizing one or more well pumps or impounded surface waters, together with elevated storage, economy dictates that the supply works be built to provide maximum domestic consumption and that the fire demand be placed in elevated storage by excess pumpage at a slow rate. Too often the amount of storage is limited by topographical conditions, but the greatest problem lies in standpipe and elevated tank structures. Where the quantity of storage is practically the only flexible expenditure in the water works system, it is natural that economies be effected by reducing storage capacity. If this reduction were compensated by increased pumping capacity, no harmful effects would be felt, but the usual rule is to tailor the supply works to feed domestic consumption so that the effect in reduction takes place entirely in fire protection. This is particularly noticeable in the use of standpipe storage, too often erected in limited diameter, where the rapid drop in head under fire draft results in a serious drop-off in the ability of the distribution system to deliver quantity, and of the storage to endure.

Vital Function of Distribution System

In the final analysis, the water system is only as effective as the limitations of its distribution system. Much has been said about the evils of distribution. Some of stones cast at designers and operators are, without a doubt, justified, but it is too seldom realized that the long life expectancy of underground pipe inevitably means that the present day designer and operator are working with a heritage of errors, mistakes and omissions from one or more generations. For many years, sizes in distribution were calculated largely on the population curve of domestic use. The fire load was considered a necessary evil but not too important. Again, these arterials and distributors were usually based on new pipe efficiency, which, in the lack of chemical control, invariably fell off rapidly. For general purposes in applying the grading schedule, pipe efficiency is calculated by the Williams-Hazen formula, using a coefficient of 100, supposedly equivalent to mid-life expectancy in cast iron. There has been a great deal of discussion regarding the use of this coefficient, but it probably approaches the truth.

The writer has made as many as 50 loss-of-head tests on a single water system and found coefficients ranging from 52 to 120, with an average coefficient of 85. The only way in which the present day designer can overcome the local deficiencies in distribution, made prior to his time, is deliberately to compensate in increased pipe sizes, thereby reducing the total loss of head to the ultimate point of use. In justice to the water works profession it must be admitted that the largest single factor in distribution evils is the lack of structural continuity in the American city. In the absence of zoning provisions many small residential communities may, almost overnight, be transformed into industrial cities. It is common practice for a college, institutional home or other place of large assembly to locate in the center of a residential community, immediately increasing the fire demand by 300 to 500 per cent, with no provision for meeting that necessity. Not a few of the most costly fires, in life and property, have resulted from such conditions. Without strict zoning limitations it was, and is, impossible for the designer to calculate the size of feed and arterial mains to care for such possibilities. For years it was thought that 4-inch minor distributors were of ample size to care for the local domestic and fire load. It is only recently that the false economy of this size of pipe has been recognized gener-

ally and that many public and private systems have established a definite minimum pipe size of 6 in. for future installations.

Some of the deficiencies in distribution have been minimized by the modern motor pumper with its ability to take care of hydrant supply at any residual head down to 20 in. of vacuum, and to deliver at any discharge pressure up to 300 lb. The question, then, has become not one of high residual pressure, but rather of volume. With the rapid growth of zoning, there is, at last, the possibility of fairly accurate calculation in the installation of feed and arterial mains. The restrictions offered in the zoning ordinance show the way for projecting a balanced distribution system into the future development of the community.

The Factor of Reliability

In regard to reliability, the author intended to view the subject of water supply for fire protection in line with conventional practice for economical water works design, with an appendix dealing with what may be termed "War Risks." It is, however, impossible to segregate these two factors. In a recent address, Charles Haydock, Committee Chairman of the Pennsylvania Water Works Association, outlined the vulnerability to sabotage and attack of typical water works structures. One evening recently a foreign broadcast from London cited the authoritative statement that no city could endure without electricity, transportation and pure water for sanitary purposes, and of these three water is obviously the most essential. Details from war zones are meager, but it requires but little imagination to visualize the pestilence and misery that fell in the wake of the siege of Warsaw. If there is any lesson in the European scene of the past year, and in our own hysteria over delayed defense measures and the billions of dollars involved, it is that the reliability of water works structure must include ideas foreign to our habit of economical design and construction.

This added factor, however, is in line with present rating schedule practice. It needs but further extension of those practices to reduce the potential hazard of war risk. The reliability of low lift pumpage is probably the least of these troubles since present-day fire apparatus, with powerful and reliable motors and highly efficient pumps, can be utilized to replace temporarily the damaged low lift units. Reliability of service in the remainder of the supply works structure calls for a duplication of units that defeats any idea of true economy.

The schedule contemplates the out-of-service possibilities of one and two high lift pumping units in considering the plant ability to handle the maximum load. To concentrate these units in one pump pit has always been considered economical design, but nevertheless a dangerous practice. Reference may be made, for example, to the interruption of service in Buffalo, N. Y., on January 3, 1940. In the Colonel Ward pumping station of that city are concentrated three 15,000,000-gallon service pumps, all located in a pit 15 ft. deep, without provision for adequate drainage; high pressure fire service pumps are also located in the same pit. Rupture of a 60-inch cast-iron discharge line flooded the pump pit, resulting in an out-of-service period of approximately 12 hr. In 1933, high water at the confluence of the Schuylkill River and Pickering Creek resulted in flooding completely the 14,000,000-gallon plant of the Philadelphia Suburban Water Co., with an out-of-service period of approximately 15 hr. Many other examples to prove the necessity for decentralization of supply works to protect against the normal hazards of power failure, fire and flood waters are available. The element of war risk only intensifies the extent to which this decentralization should be carried. It is possible in many cases, particularly in small communities, to compensate for these hazards by adequate elevated clear water storage, limited, of course, below the point where stagnation may affect potability. In the larger cities, however, considerable expenditure would seem to be justified in the installation of raw water force mains to small purification units.

Pumping station design in recent years has shown a strong trend away from direct steam power and toward electricity as a prime mover. Reliability in this respect has been greatly increased by the development of interlocking transmission systems in the power companies. At the same time, power generated at a distance from the supply works, is subject to the natural hazards of weather, which, like the New England hurricane of 1938, may be so widespread as to affect all the normal interlocking lines. For many reasons the safest arrangement for water works operation will include two distinct sources of power. Both diesel and internal combustion engines have been developed to a point where reliability is secure. Their use for standby service has been increasingly successful. Especially in the small to moderate size plants, the multiple use of limited size diesels provides a high degree of reliability.

It is quite evident from the investigation of water works that the desire to reduce inventory of spare pipe valves, fittings, flanges and the hundred other items necessary to continuous operation often reaches a hazardous point. It is a proved fact that in times of stress it becomes increasingly difficult to obtain these items upon short notice. This consideration will hold true throughout the entire water works structure including distribution. It would seem that a semi-annual check-up of the inventory of supplies against the peculiarities of the individual system should be a matter of routine.

Bottlenecks in Treated Supply

Many years ago considerable credit was given under the grading schedule for available raw water supplies. It was common to find complete bypass arrangements whereby sedimentation, filtration and chemical purification could be eliminated conveniently. With the rapid growth of sanitary control by state authority, the majority of such bypasses have been either sealed off or entirely broken away from the possibility of use. There will be no argument that this is entirely fitting and proper, due to the great difficulties in sterilizing the system after the raw water has been used. The fear of water-borne epidemics has rightfully hung over the heads of water works men for many years. To their recognition of the dangers and their unceasing vigilance may be given most of the credit for the remarkable record attained in this field. The weak link in supply works, however, is too often found in filtration capacity. When clear water storage is inadequate to handle a fire of extended duration, the system becomes limited by the rate of flow through the filters. While the schedule credits a 50 per cent overload on the normal rapid sand filter, one or more of the units must be considered out of service for the necessary wash period, as well as for the inevitable rebuilding. For years small filter units—for normal conditions, 0.5- to 1.0-m.g.d. units in sufficient number to provide the necessary reserve—have been advocated. Considering how vulnerable to natural accident and planned destruction is the usual filter gallery with its monolithic concrete structure, manifolded wash water and discharge piping, underlying clear water storage, it seems evident that these large filter multiples should, in the future, be broken down to smaller plants, each complete in itself, and with sufficient segregation to insure complete independence. Here, again, the need for considering a total revision of the conven-

tional economic design must be stressed. It will become a major concern of the water works designer to calculate how far afield he may go from economy of design and maintenance to secure the necessary reliability of service indicated by current events.

Further in regard to the reliability of service, it may well be said that reconsideration of the present conventional practice of installing pipes with a cover regulated by frost depth is necessary. Present practice usually indicates the use of from 3 to $3\frac{1}{2}$ ft. of cover, although the changing street grades, after installation, often reduce this figure to a dangerous point. The first reason for increased depth of trench is the incredible increase of the amount and type of traffic. Some years ago the only traffic danger was the trolley car, but the usually well-ballasted road bed tended to disperse the shock load. In these days, however, it is quite common to find truck and trailer loads of 50,000 lb. with per tire loads up to 4,500 lb., traveling at speeds of 25 to 35 m.p.h. in closely built communities, and up to 60 m.p.h. on the open roads. The many pipe failures due to the vibration and shock load of such vehicles are among the factors which have led to pipe installations in sidewalk or parking areas, but even here the value of additional cover should not be overlooked. Many stories from the war zone cite the destruction of utility services from bomb craters in the streets of congested districts. Whether or not increased cover would protect against this hazard must remain problematical until detailed information can be received from the war areas.

Importance of Maintaining Valves

This last consideration also brings up the necessity for adequate and properly maintained valving. It is perhaps a tribute to the efficiency of modern water systems that the operator feels so confident of his freedom from trouble that he is prone to neglect the maintenance of the valve system. Thus in most water engineer's offices will be found dip needles and radio pipe finders of every description, placed there largely because of the knowledge that if it does become necessary to operate a valve it will be necessary first to locate it under the one or more coatings of street paving. It is axiomatic that the valve which is not operated periodically will finally become inoperable through the action of frost, ice, dried packing glands or the filling of the valve box with debris. So many instances are on record, and incidents where the failure of one valve has caused a total cessation of water service are so familiar, that it is not necessary to cite

any examples. While there are always principal controlling valves in any system that are points of obvious hazard, it must be realized that every valve is necessary to the reliability of distribution. After years of neglect, the first valve survey will be found an expensive and difficult undertaking, but periodical inspections are simple and economical and should be made a matter of routine.

Adequate Hydrant Provisions

Most fire protection engineers become more or less fanatics upon the subject of hydrants, their number, size, type and spacing. The writer has presented the following argument to the point of boredom to his listeners, but it must be reiterated that the basic value of the water system is too often lost by the lack of adequate hydrant provisions. Undoubtedly the most exasperating feature of water supply investigation is to encounter a system adequate in source of supply, storage, treatment and pumpage and complete in force, feed, arterials and distributing mains, with 35 to 75 per cent of the investment dictated by the fire demand, and then to discover that the hydrants are spaced at a coverage of 500,000 sq.ft., resulting in almost complete nullification of the investment value. Some years ago, an alphabetical list covering 83 protected fire zones within the Middle Department Rating Association's underwriting territory was made. An average built upon area of 343,000 sq.ft. in systems privately owned, and 218,000 sq.ft. in public ownership was found. Among these systems, two privately served communities with average spacing of from 900,000 to 1,000,000 sq.ft. were discovered.

The schedule sets up a very logical basis for hydrant coverage which varies in inverse ratio to the fire demand from 120,000 sq.ft. at 1,000 g.p.m. fire flow to 40,000 sq.ft. at 12,000 g.p.m., but, in general, hydrant protection in any amount will usually follow long after installation of the pipe system itself. The rapid increase in dwelling construction during the past two years has developed the same problem all over again in the difficulty of getting proper hydrant protection.

It is only natural that this situation is aggravated in systems under private ownership, a direct result of the flat-rental basis, where every hydrant installation means a permanent addition to the municipal budget and is usually regarded as a personal insult to the finance committee. The flat-rental basis for fire protection does not obtain good results because it produces a natural tendency to limit the number of

hydrants to a minimum. It naturally follows, considering that the greater part of fire protection costs is assessable against the investment in plant and distribution, especially where one company serves several communities, that the area with the closest hydrant spacing is paying more than its share of the plant costs. Many papers have been written on this subject and several systems of fire protection charges have been recommended and put in service, particularly the "length-of-main" basis, together with the refinements that have produced the "inch-foot" system, but neither of these has attained widespread use. A plan of fire protection costs, equitable to the community as well as to the producer, that will encourage hydrant installation rather than to defeat that purpose, is obviously a major necessity.

In this matter of hydrant spacing, the rating organizations are often of considerable aid to water officials in that they are often equipped with structural plans of the community and familiar with the apparatus layout as well as with the required demand for the particular location.

It should be emphasized that without the cordial relations between the stock fire insurance groups and water works officials, the work of such rating organizations would be handicapped to an almost impossible point. These relations are not cordial by accident but are the direct result of a sincerity of purpose on each side. The single aim of both operator and critic is to produce and maintain the best possible water system. Standards agree because they originally came from the water works field and are constantly adjusted to the results of experience and progress in that field. It is, of course, the aim of the rating organization to keep relations at that high level of co-operativeness.

What an Operator Expects From a Salesman

By L. A. Nalefski

Illustrated by H. W. Montague

THAT an operator expects more of a salesman than a medium for transmitting orders goes without saying. Just what he expects seems to depend in great measure on his own training and experience, but, in any case, the consensus of opinion of operators, superintendents and health officers, in general, indicates three definite requirements which every salesman must meet in all his contacts. These, in order of their importance, are integrity, familiarity with his products and acquaintance with new developments in his particular field.

The Operator's Ideal Salesman

In addition to these primary requisites of a good salesman, a number of other considerations which must be classed as desirable characteristics rather than absolute requirements are also pointed out by most operators. These latter demands upon the salesman, however, must be associated with the personalities of those who require them, and, therefore, vary considerably from customer to customer. Actually, of course, many of them are concerned with the personality traits of each particular salesman and so cannot be reduced to any definite standard. Others involve the particular intricacies of the system under which the salesman works, and since these vary with each company, it is difficult again to set any standard requirements. In discussing these incidental considerations, here,

A paper presented on April 29, 1941, at the Illinois Section Meeting, Quincy, Ill., by L. A. Nalefski, Chemist, Water Works Department, Decatur, Ill.

Caveat Emptor—and the devil take the hindermost

the author intends only to indicate those particular failings which seem to arouse the greatest amount of friction in the operator-salesman relationship—the "pet peeves" of the operator.

In regard to the first requirement of a good salesman—integrity—little need be said. That the time-honored adage, "honesty is the best policy," applies is apparent. Little "white" lies should be eliminated completely as a sales technique, both as they apply to the product in question and to that of a competitor. Unguarded statements or statements made without careful reservations do not often make sales and never make repeat sales. Even slips of the tongue made by an uncautious salesman will arouse suspicion in the mind of the operator so that he will instinctively guard against making a purchase though it might be to his own advantage. It must be realized that the days of the *caveat emptor* doctrine passed centuries ago, and that today a buyer expects to know what he is getting for his money.

It might be well here to point out, too, that the salesman has the same right to expect an honest opinion. Operators, themselves, are not always free from questionable practices. The "clever" fellows who continually intimate that an imaginary competitor is willing to offer a better estimate should bear in mind that the manufacturer, too, must exist and buy materials and pay employees for producing the products. Only an honest, mutual understanding of the problem at hand will lead to a satisfactory solution.

That the salesman should know his product is again an obvious requisite. Certainly the salesman, himself, is more keenly aware of this than is the operator to whom he is trying to sell. Every salesman should be well versed with the structure, chemical composition, etc., of his product. He should have all of his information assembled and on hand to dispense at the time the discussion is taking place. Writing to the home office for additional information from the technical staff is not only time consuming but very discrediting. If the product is of secret or patented preparation, he should inform the prospective buyer immediately of this fact. One superintendent,

with whom the author is acquainted, is particularly opposed to oil salesmen because of their secretive air and their failure to produce scientific basis for their claims concerning their product. He points out that a simple statement to the effect that this information cannot be provided because of the secrecy of the processes would make for a much more satisfactory attitude.

It is essential that the operator know the capabilities and limitations of the equipment in which he is interested if he is to make a wise selection. For this information he depends upon his salesman. If the salesman realizes that his product will not meet the demands of the job on hand, he should inform the superintendent or engineer to that effect immediately rather than to attempt to provide equipment which will render only a fraction of the expected performance. Contacts with salesmen who are willing to forego sales for such reasons have caused many operators to look upon them with more respect and to seek their aid and judgment in future needs. The small plant operator depends upon the salesmen completely in this respect, because he recognizes the fact that he, himself, does not possess sufficient training or experience to make a proper analysis.

In regard to the salesman's duty of advising operators of current research and development, it is generally known in this present age of revolutionary industrial development that manufacturers have established laboratories for research and development of new and more efficient equipment. It would be a gigantic undertaking to attempt to publish all of the results of such research. Even that which is published often does not reach a majority of the operators because in many of the smaller plants no time is allocated to the operator for studying and no funds are available for obtaining the literature, so operators expect the salesmen to come to their plants and keep them informed of new developments.

"See how they run"

In this connection, too, it is felt that the descriptive advertising literature to which operators are now exposed could be improved considerably. It appears, from much of the data in the colorful brochures, that manufacturers are under the impression that

operators are primarily interested in modern streamlining and appearances in general. The descriptive publications could be of much more value if they dealt with the more pertinent data of operation and specifications.

In general it has been found that an operator expects concrete facts and figures from a salesman. A salesman who can show by figures in a concise form just how his product will save the operator money or make his job easier is always welcomed by the operator. Demonstrations, in many instances, can bring out points which a flood of literature cannot. Charts and diagrams aid very greatly in helping to present a clearer picture.

Operators of today are pleased with the fact that some manufacturers have made a practice of developing laboratory models or pilot plants to demonstrate the operation of their equipment as well as of the fact that chemical companies are usually willing to send a technical representative to a plant to make actual trial runs to test the practicability of using a particular product. These approaches are to be encouraged, since it is known to an experienced operator that the problems of different plants usually have their own peculiarities and do not respond to universal cures. Thus, by actual trial in the operator's plant, an intelligent conclusion can be drawn.

Since salesmen cover a great deal of territory and visit many plants operating under various conditions, they are in a position to absorb an abundance of information regarding different approaches to similar problems. By mentally cataloging this information, they can be of great service to operators at other plants in which a solution has not been reached as successfully. Many tricks of operation can be spread through the field in this manner. Some operators find through experience that a certain approach to a problem will net the best results, but feel that the materia is of minor importance and not worthy of reporting in the literature. In such cases the ideas die with the operators, unless, through an alert salesman, they can be dispersed throughout the profession and be profitable to many. A word of caution might be introduced here regarding the certain skeletons in every operator's closet, which are intended to be more or less private. Discretion in this and similar matters should be carefully exercised.

These have all been matters pertinent to the primary requisites of a good salesman, and close conformity with the suggestions made

should certainly result in a mutually profitable relationship between the operators and salesmen. It is to be emphasized again that these are the factors of major concern to operators in their contact with salesmen and that those incidental considerations which are now to be discussed, though they do carry more or less weight with various operators, are actually of only secondary importance. Six of these particular "peeves" are as follows:

Panacea Pest in Action

1. The time consumed by some salesmen in making routine calls appears to be annoying to some operators. They feel that the salesman should take time to relate any experiences which might interest them in connection with the operation of their plants, or to explain and describe new equipment or products which have been developed, and, having done this, to leave immediately. The author, however, rather enjoys most of the time he spends in visiting with salesmen at the plant and invariably, learns something advantageous to himself in such casual conversation.

2. Failure of the salesman to contact the proper person appears to be a "social blunder" of the first order; it seems to injure the pride of the operators. They feel that they are aware of all of the details of their plants including its shortcomings, and that to discuss these matters with someone in the office "uptown" is almost sacrilegious, the outcome of which will be further difficulty resulting from the false picture of the problem obtained in this manner. Many salesmen are respected for their consideration in searching out the proper person with whom to discuss the plant's problems.

3. A particular irritation among operators is the salesman's method of handling information concerning prices of equipment. This is especially true of those operators who have a limited appropriation on which to operate. It is the opinion of some operators that many manufacturers have no fixed prices for their equipment, but attempt to get as much out of it as they can. If this is the case, of course, it probably benefits the small operator more than it does the larger one, since it is an established fact, in most cases, that the smaller the

The "Wine, Women and Song" Technique

plant is, the smaller the appropriation. The solution to the problem would be to publish prices of equipment and replacement parts at regular intervals. In this respect chemical manufacturers probably have the most clean-cut system for submitting information concerning costs of materials. There is no effort made to conceal the information from competitors, as price lists are published at regular intervals. The lime manufacturers, however, are still a little lax in this matter, perhaps because of the rather close competition in this field.

4. Panacea salesmen are another source of operator irritation. Those salesmen who concoct tremendous tales of the miraculous properties of their products are too well-known to require further discussion; and the necessity for elimination of such sales technique is just as clear as it has been in the patent-medicine business.

5. The elimination of local dealers would also make many operators happy. It appears to them that the 10 per cent or more "rake-off" which the local dealer realizes could be put to more advantage in reducing the initial cost of the material to the ultimate consumer.

6. Finally, to a certain group of operators, those salesmen who attempt to sell their products with the aid of "wine, women, and song" are particularly irritating. The author is not in a position to discuss this matter since he has had no opportunity to be exposed to that type of technique. Obviously, however, the operator is open to as much, if not more, criticism than is the salesman. Certainly no operator has ever been injured in the attempt to prevent such high sales pressure from being applied; and from the appearance of some salesmen on the morning after such escapades, it is difficult, too, to believe that they enjoy that type of saleswork.

Before closing this discussion, something should be said of the social relationship between the operator and the salesman. Everyone knows that salesmen turn out in great numbers for each convention. In fact, it is not certain that the meetings would be nearly so frequent if this were not the case. They always seem willing to do

more than their part to make the conventions a success and many operators attend knowing that they will have an opportunity to meet some of their salesmen acquaintances whom they have had no occasion to contact for some time. At such affairs salesmen are notably polite and willing to do everything in their power to make the operators enjoy themselves. On the other hand, operators attending conventions know that these salesmen will be present and willing to entertain them, and some operators can be criticized for taking too great advantage of this hospitality.

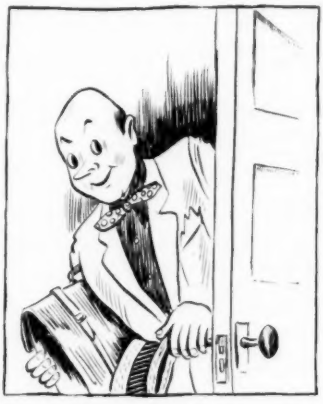
In closing, the author wishes to stress that salesmen are among his best friends, and that this discussion is not personal, but made up from interviews and experiences with operators, salesmen, and health officers.

What a Salesman Can Offer an Operator

By Edward E. Alt

Illustrated by H. W. Montague

PERHAPS the best approach to a discussion of what a salesman can offer a water works operator is an indication of what the salesman expects from the operator, as that is a prerequisite to his being able to offer anything. Generally speaking, the salesman expects only an unbiased audience. Too many operators are satisfied to sit back and follow old established methods and to purchase the old so-called "standard" water works equipment, which has been used in their plants for 20, 30 or even 40 years, so the most difficult job which confronts the salesman is to gain the interest of the operator to the point of obtaining a successful interview.



Generally speaking, the salesman expects only an unbiased audience

A salesman of proper background and training is usually an engineer of college training who has a complete knowledge of his products, and, therefore, has the right to expect the interest of a customer. It should be obvious, from the fact that his company is spending money to keep him on the road, that he has something to offer, and a progressive operator is constantly on the alert for what anyone in his field can offer. Once the salesman is granted an audience it remains for him to make the interview worthwhile to the operator. To do this he must more than merely attempt to advance the sale of the products which it is his job to promote, and this he is able to do

A paper presented on April 29, 1941, at the Illinois Section Meeting, Quincy, Ill., by Edward E. Alt, Engineer, Chicago Bridge & Iron Company, Chicago.

because of the variety of his contacts and associations, and because of his familiarity with new developments in the field.

Salesman as an Information Bureau

The average water works operator, even though he is a member of the A. W. W. A. and similar organizations, does not have the time to read all the information made available in the JOURNAL and other publications. As a matter of fact, much of the current research work in the field is not publicized until a final report is available for publication, so that the majority of operators, and even a large number of consulting engineers, are not familiar with developments until they are formally presented. During the developmental stages of such work it is usually the salesman who is the only medium for transmitting the information to those who will benefit by it.

Due to the large area in which he is active, the salesman can be of further assistance to the operator in advising him concerning the method by which other plants in other territories have met problems similar to his. Almost every operator has some particular problem, the solution of which will be facilitated by the knowledge of similar experiences in other plants, and the salesman can provide this information readily.

A division manager of a large public utility, in addressing his staff, once expressed the value of this service in the following words: "Whenever a salesman calls on you, welcome him into your office. Sit down and listen to him, because, before he leaves, he will have told you something that will be beneficial to both yourself and your company. Remember this, that he calls on hundreds of people every month and, in his travels, is able, in one month, to pick up more good information than you will be able to hear on your jobs in five years."

Salesman as a Trained Advisor

It must be realized too that a salesman in one particular line of water works equipment has a highly specialized training in that one line and, therefore, is able to counsel operators in the intricacies of that specific field. Furthermore, the salesman has access to data on changing market conditions—price advances, delivery changes, etc.—which permit him to assist the operator in planning his future purchasing program. In all these ways he may be of direct assistance to the operators who are his prospective customers.

More directly a part of his job, the salesman also offers service to the operator as a direct representative of his company after a purchase has been effected. At that stage it is the salesman's task to iron out any difficulties with delivery and installation of the equipment, and to keep a constant check on its performance once in service. In this way he maintains his contact with the operator and is available with constructive suggestions and new information concerning the operation and maintenance of the eqipment he has sold.

The salesman follows through after a purchase has been effected

Aside from the purely technical and business aspects of the operator-salesman contact, some mention should also be made of the opportunities offered for social relationship. Many fine friendships result from the various social contacts that are built upon the business dealings of the men concerned. These are personal affairs which are sanctioned unqualifiedly by all reputable manufacturing concerns and which cannot be construed as "buying" an order or influencing a prospect, when, as in most cases, they are the result of a mutual desire for personal association.

These are the various benefits which a salesman offers an operator aside from the prosaic matter of writing orders, and it is upon this basis that the relationship can be made into a mutually profitable one. Such an understanding, too, should result in direct benefit to the water works field as a whole.

Utility Co-ordination in Emergencies

By L. A. Geupel

ABOUT a year ago the Indiana Section of the A. W. W. A. formed its Technical Committee, under which sub-committees to investigate and report in detail on the various problems of the water works field were appointed. As Chairman of the Sub-Committee on Emergencies, the author will report on the work which has been and is being done in that field.

Initial investigations of the sub-committee indicated that all possible help from executives of the municipalities and from other sources concerned would be necessary to the success of the study. To obtain such assistance, the committee first appealed to the Municipal League of Indiana and from it received the promise of full and immediate co-operation, all the mayors of the state being advised to that effect in a letter sent out by the League's Executive Secretary. Next, the committee appeared before the City Engineers Group of the Purdue Road School and received its endorsement. Finally, in addition to these pledges of support, other organizations did their part in furthering the plan. The State Board of Health, for instance, co-operated splendidly both by direct assistance and by publicizing the work in its magazine, the *Water Spout*. The A. W. W. A., too, indicated its approval of the project and urged that more detailed information be obtained from all plants.

As the work progressed it was found that the task was too great for a single committee, so it was necessary to sectionalize the state, employing sub-divisions of the established State Board of Health Districts (Fig. 1). Because of the short time at hand, the chairman of the sub-committee, acting upon the advice of the Chairman of the Technical Committee, had to ask certain men in the various districts

A paper presented on April 24, 1941, at the Indiana Section Meeting, Indianapolis, Ind., by L. A. Geupel, Superintendent, Water Works Department, Evansville, Ind.

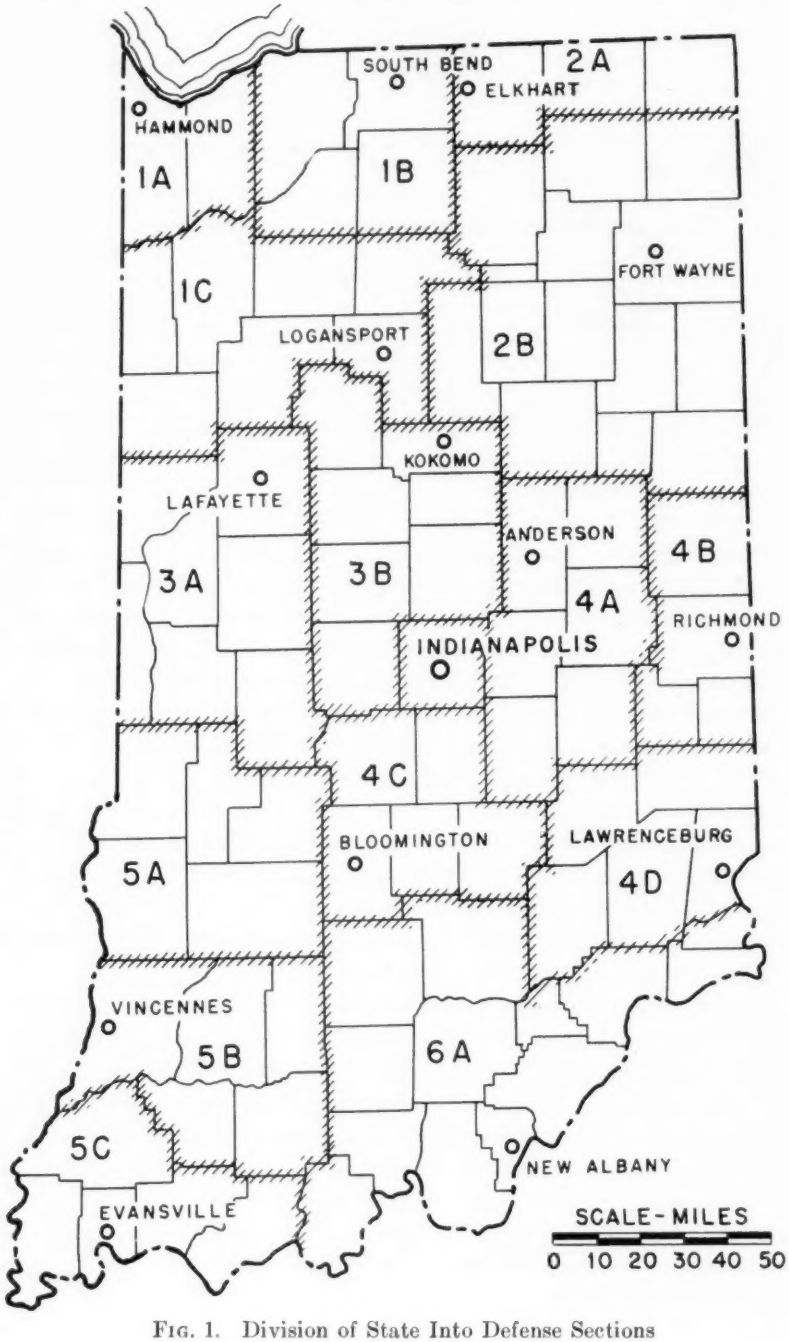


FIG. 1. Division of State Into Defense Sections

to act as section chiefs. With each such request, questionnaires and recommendations by the committee for distribution to the water works in that section were forwarded to these key men. Replies were received from all fifteen appointees accepting the responsibility and reporting that letters and questionnaires had been distributed as requested.

Recommendations to Operators

In the material distributed in this way were contained the following recommendations for the consideration of all utility operators:

1. That operators carry in stock a reasonable and even extra supply of the necessary spare parts, i.e., bearings, chlorinator parts, meter parts, spare parts for hydrants, valve parts, etc.—in other words, such items as are now difficult to obtain.

It must be explained that it is not intended that anyone buy out the spare parts market, for it is realized that the national defense administration expects every utility to "stand on its own feet," and that it is only fair for the utilities to be out of the machine and tool and die shop so that they may apply their total productive capacity to the needs of armament. It is to be pointed out too that it would be impossible for any one utility operator to tell another just the spare parts he most needs. It is known that, at best, many of the utilities will be "caught short," and unavoidably so.

2. That operators carry in stock a reasonable and even extra amount of materials, good operating equipment and supplies at all time. By materials are meant pipe, valves, hydrants, meters, fittings, chemicals and such other materials as are the constant requirements for operation.

3. That each utility operator and executive inform himself about, and have available a list of, contractors' power equipment, owned and operated by the contractors in and around each city or town. It is recognized that such equipment is moved about on various jobs, but it would be worth while to know the whereabouts of power shovels, drag lines, pumps, portable air compressors and breakers, etc. at all times. If the need does occur, it will be of great value to know where such equipment may be borrowed, rented, requisitioned or obtained in some manner.

4. That the superintendent and principal foremen of each utility make a serious study and review of its fire hydrant and valve control layout, so that broken mains with their connecting hydrants and

valves may be shut off and controlled speedily in the face of a serious fire or conflagration. In this connection it must be pointed out that there is no place in such an emergency for the "one man who knows it all," or for the "little black book." Every superintendent should be absolutely certain that his principal men know their distribution control valve system and that there is posted and easily available the full layout of the distribution system, showing hydrants and valves.

5. That, in accordance with present practice, visiting at any water works or other utility plant be curtailed to a minimum and that those who are admitted be registered and escorted through the plant by trusted employees. Heretofore it has always been the policy of the utilities to show any and all visitors through the plant at all times. Times are no longer normal and peaceful, however, and in cities where large industrial armament parts and equipment, munitions, airplane and other plants are in operation, utility men must show caution and be "on their toes" to guard against carelessness, ruthlessness and even isolated sabotage. It is to be noted that continuous operation of all utilities is the life stream of industrial activity, so all strangers visiting the plant and grounds promiscuously must be given close scrutiny.

6. That every community and city consider and organize an "ex-officio" committee to include the accredited representative of all utilities operating in that city as well as the chief of the fire department, the chief of police, the city engineer, the director of public works and safety, the financial and legal representative designated, and the building commissioner. This committee, after organization of members, should operate without publicity and should be subject to the call of the mayor at any time to decide and function on emergencies of any nature or kind. Only the committee as a whole should have authority to decide the publicity to be given out; and the meetings should not be considered public meetings unless the committee as a whole so decides. This committee should have a separate meeting room where maps and layouts of streets, water mains, power lines, gas mains, sewers, etc., may be kept on display for quick use. The quorum should act as a "committee as a whole" and each member should co-operate to the fullest extent. No orders are to be transmitted except as co-operatively acted upon and approved by the mayor.

Status of Indiana Plants

Replies to the questionnaire, which was included with the recommendations, were received from 75 water works in six sections of the state. A study of the answers to the various questions showed that: 71, 95 per cent of those reported, have sufficient spare parts; 73, 97 per cent, have sufficient materials on hand; 70, 90 per cent, have valves and hydrants under control; 60, 80 per cent, have visitors under control and know their men; 42, 56 per cent, are located in cities which have committees for emergencies; and 56, 75 per cent, have knowledge of contractors' equipment in their vicinity.

In the above report, representing about 25 per cent of all water supplies in the state and taking into consideration a cross-section of the state, it is indicated that water works men are co-operating as much as possible toward preparing an adequate program for emergencies.

Organization in Connecticut

A quotation from a letter to the author, giving a brief summary of the status of this type of work in another state, will give some indication of its possibilities:

"The water companies in Connecticut have done a very nice job in the same fashion, particularly in the direction of developing a clearing house record of stocks or repair materials. Here was one difficulty that developed and you can point it out to your people. Some of the superintendents who turned in a list of stock items overlooked the fact that when one of these items was taken out of stock and installed they should at once reorder that item and put it back into stock. Three or four instances developed where one superintendent would make reference to the stock list that had been assembled for the entire state and go over to the neighboring community to get a piece of equipment and then find out that that superintendent had put it into his own system and had said nothing about it. The only substitute for immediate replacement of repair items would be a postcard memorandum to every individual having a copy of the stock list, saying that the particular unit was no longer available.

"Here again in this interchange of stock information water works superintendents are in a position to improve their routine administra-

tive practices. The policy of mutual aid is just as good in times of peace as it is in times of military stress and there isn't any particular reason why the water works superintendent in Princeton in an emergency should not be able to call upon the superintendent in Washington, Terre Haute or Evansville."

Type of Questionnaire

The viewpoint of one section chief regarding the form of the questionnaire is that it should come from state officials through the mayors to the water department so as to give a compulsory or "must answer" action. The author, however, is of the opinion that water works men, as a co-operative group, can still help each other without resorting to the compulsory spirit. All that must be done is to encourage a friendly reaction and an Association contact and results will be obtained. Further, it is believed that any questionnaires which the State Fire Marshal, the State Police Chief's Association, or the Governor's Defense Commission may wish to send out be presented through the State Board of Health co-operating with the Association's emergency or advisory board. It is felt that too many questionnaires from different sources will only result in confusion and the collection of a group of miscellaneous and unrelated data. In other words, a reasonable single questionnaire could answer all the questions for information needed, and a central agency could distribute the information to all agencies or commissions requiring facts.

In summary, it must be emphasized that the principal men of the utilities will have a great deal of responsibility. No "flag raising" or even press or public appreciation is contemplated, but a quiet and determined effort on the part of utility men to stand on their own feet and get ahead of the emergencies which may arise is planned.

Recent Stream Pollution Studies in West Virginia

By K. S. Watson

FOR a number of years, a water odor, unidentified in nature until recently, has been present in the Kanawha river below Charleston, W. Va. This odor has been of sufficient intensity to cause ever-increasing treatment troubles in the downstream water plants at Saint Albans, Nitro, Winfield and Huntington. In addition to this, spasmodic occurrences of an odor of different origin, also the cause of treatment difficulties, have also been noted in the Elk River at the Charleston water plant intakes. It was to obtain further information concerning the type, source and time of occurrence of these trouble-producing odors that the surveys to be described here were undertaken. Before proceeding with a discussion of those investigations, however, the author would like to outline the legislation and administrative agencies of the state stream pollution abatement program which made such surveys possible.

In 1929, an act passed by the state legislature provided that the commissioner of health, the chairman of the public service commission and the chairman of the game and fish commission and their successors in office should constitute a state water commission, the duty of which was to administer a program of stream pollution control in West Virginia. In 1933, the original State Water Commission Act was re-enacted with minor improvements; and, finally, during the 1937 session of the legislature, the act was amended to give the Commission greater enforcement authority by providing a municipal finance plan for sewage treatment works and by investing the Commission with the power to levy fines against offenders.

As it now stands, the act provides that such personnel as is thought necessary may be employed by the Commission to do the field work

A paper presented, in part, on October 26, 1940, at the West Virginia Section Meeting, Huntington, W. Va., by K. S. Watson, Chemical Engineer, State Water Commission, Charleston, W. Va.

in carrying forward a pollution control program; and under this authority it has been the practice of the Commission to employ a chemical engineer to make the inspections and surveys necessary to prosecute the program. By the act, too, the director of the Division of Sanitary Engineering of the State Health Department is designated to perform such services as requested by the Commission, and, thus, has been supervising the activities of the chemical engineer for the Commission ever since its inception. This co-operative arrangement has served to correlate and unify the stream pollution programs of the two agencies; and it was by the action of these co-operating agencies that the surveys on the Elk and Kanawha Rivers, as described here, were carried out.

Organization of Surveys

Since a mobile laboratory of the Ohio River Pollution Survey had been doing some work in West Virginia during the fall of 1939, the State Health Department made a request to the U. S. Public Health Service for assistance in making the surveys; and in answer to the request, one of the mobile laboratory units and its crew of three men were detailed to the work during the winter months of 1939-40. In addition to these three laboratory men, who spent full time on the project, the personnel included an assistant chemical engineer of the U. S. Public Health Service and two engineers of the State Department of Health, who assisted in making the odor determinations, and the chemical engineer of the State Water Commission, who helped in collecting samples, making odor analyses, compiling data, and working with the industries.

Chemical, biochemical, bacteriological and odor analyses were run during these surveys, but since the river odor seems to have been the chief source of complaint, only the odor picture is to be considered in this paper.

The threshold odor determinations used in the surveys were run at atmospheric temperatures without the use of an osmoscope. The threshold concentrations listed here were obtained by diluting the sample with odor-free water to a point where the last trace of odor could just be detected, and then dividing the total dilution volume by the volume of the samples, both quantities being expressed in similar units. Since it was realized that no two persons would be able to detect odors in exactly the same concentration, three analysts ran all odor determinations, and the odor threshold for any sampling point for any day was listed as the average for the three individual

results. All samples were collected and numbered on the samplers' master list, so that the analysts were running the samples independently, by number, with no idea as to their origin.

Kanawha River Survey

Under this plan the Kanawha River Survey (Fig. 1) was carried out between January 29 and March 15, 1940, covering a section of

TABLE 1

Raw Water Characteristics at Nitro and Activated Carbon Fed to Correct Water Odors as Taken From West Virginia Water Service Co. Operation Records

	1934*	1935	1936†	1937	1938	1939‡
Average water filtered, *1,000 g.p.d.*	913	820	1,083	1,050	1,130	1,450
Total activated carbon fed, *lb.*	3,873	6,699	13,665	15,302	25,318	57,434
Average carbon fed, *g.p.g. per day*	0.077	0.14	0.28	0.28	0.41	0.76
Alkalinity (M.O.) *p.p.m.*	32	30	34	28	29	33
Hardness (Soap) *p.p.m.*	—	46	46	43	53	66
pH	7.0	7.0	7.0	7.0	7.2	7.3
Average river discharge, Kanawha Falls, *sec.-ft. per day*	9,415	15,640	13,710	13,430	10,677	9,239
Pool elevations, Nitro intake, *ft.*	546.4	546.4	546.4	558.0	566.0	566.0
Pool stage raises, *dates*				5/30/37 10/20/37	1/ 6/38 9/22/38	
Actual raise, *ft.*	0.0	0.0	0.0	11.6	8.0	0.0

* Results submitted by Kanawha Valley Water Corporation.

† Records were available for only 10 months.

‡ $7,000 aerator installed Aug. 30. Operating cost, 60 cents per hr.

the river extending from the London Locks to Winfield Locks, a distance of 52 mi.

Table 1 was prepared from the West Virginia Water Service Company's operating reports from the Nitro water plant. It will be noticed that the activated carbon fed to counteract water taste and

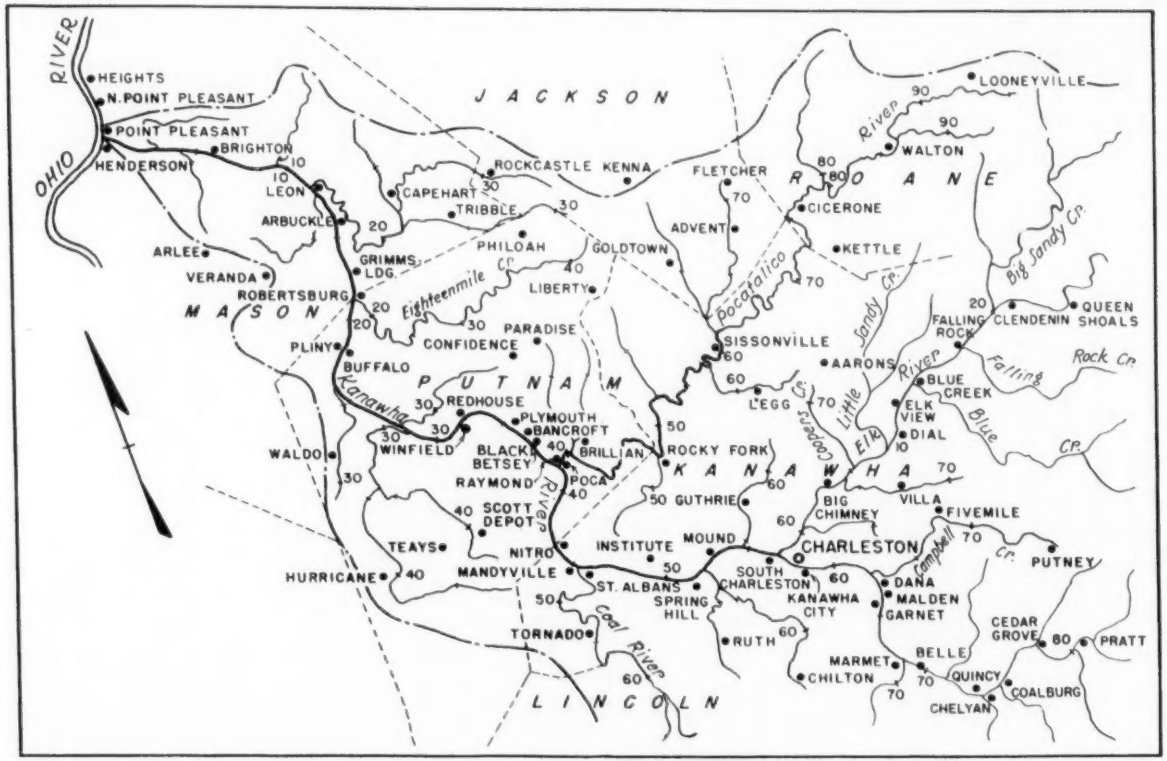


FIG. 1. Drainage Basin of the Kanawha River; showing area of pollution survey

odor increased ten times between 1934 and 1939, even though the river discharge was about the same during those two years. This increase continued in spite of the installation in 1939 of an aerator for odor reduction in the raw water.

Table 2 was prepared from the West Virginia Water Service Company's reports from the town of Saint Albans. An increase of 120-fold between 1937 and 1939 in carbon fed serves to demonstrate the

TABLE 2

Carbon Fed at St. Albans Water Plant as Taken From Monthly Operation Records

MONTHS	1937		1938		1939	
	Total	Ave.	Total	Ave.	Total	Ave.
	lb.	*g.p.g.*	*lb.*	*g.p.g.*	*lb.*	*g.p.g.*
Jan.	0.0	0.0	0.0	0.0	5.95	0.218
Feb.	0.0	0.0	0.0	0.0	0.0	0.0
Mar.	0.0	0.0	0.0	0.0	0.0	0.0
Apr.	0.0	0.0	0.0	0.0	0.0	0.0
May	0.0	0.0	0.0	0.0	13.4	0.412
June	0.0	0.0	0.0	0.0	7.6	0.242
July	0.0	0.0	0.0	0.0	13.8	0.430
Aug.*	0.0	0.0	1.06	0.033	7.45	0.222
Sept.	0.0	0.0	10.05	0.315	19.15	0.517
Oct.	1.9	0.069	37.2	1.27	61.90	1.76
Nov.	0.0	0.0	20.2	0.693	59.0	1.68
Dec.	1.77	0.0593	6.7	0.237	382.0	10.50
Yearly Total.	3.67	0.1283	75.21	2.548	570.25	15.99
Yearly Ave.	0.30	0.0107	6.27	0.212	47.52	1.33

	FEET RAISED	DATE	FEET RAISED	DATE
Pool stage raises	1.35	5/30/37	5.15	1/ 6/38
	2.00	10/20/37	2.85	9/22/38

* West Virginia Water Service Co. took over the plant August 1, 1937.

increase of odor in the mouth of the Coal River resulting from the backing up of Kanawha River water into the lower Coal River. As indicated in the table, these raises of pool stage which backed up the Kanawha River took place at the new Winfield Locks and were consummated during 1937 and 1938.

Since existing records demonstrated the presence of an increasing odor at these two plants, the problem of locating the geographic limits of the odor was attacked by making odor analyses at nine river

sampling points between Chelyan and Winfield. The sampling points, together with the odor analyses obtained for each, are listed in Table 3. It will be observed from this table that there was little odor in the Kanawha River at the Chelyan Bridge during this survey. A high hydrogen sulfide odor, however, was generally present at the Marmet Locks. It is also evident that there was a fair amount of sweet chemical odor at the two upper bridges in Charleston.

In observing the odor results at the Patrick St. Bridge, it will be noted that, except when the river was frozen over in January, the

TABLE 3

Average Odor Threshold Analyses for Various Periods at Kanawha River Sampling Points

SAMPLING POINTS	3-DAY AVE. DEC., 1939	3-DAY AVE. JAN., 1940 (FROZEN RIVER)	5-DAY AVE. FEB., 1940	MAR. 14, 1940	GRAND AVE. 1939-1940	AVE. 1939-40, OMITTING FROZEN RIVER PERIOD	7-DAY AVE. SUMMERS 1937-38 1938 REPORT
Kanawha Falls, Discharge Figures, *sec.ft.*	2,040	2,000	8,270	6,700	5,020	6,020	6,050
Chelyan Bridge K 73.7	4	2	2		2	3	
Marmet Locks K 67.7	477†	69†	108†	327†	246†	300†	
Kanawha City Bridge K 58.8	34	73‡	57‡	100†	62	52	19
C. and O. Bridge K 58.1	—	115‡	72‡	—	103	72	
Patrick St. Bridge K 56.3	31‡	332‡	49‡	15	112	39	17
St. Albans Bridge K 46.3	206*	163*	102*	43*	142*	134*	144*
Nitro Water Plant Intake K 43.3	—	128*	69*	60*	90*	67*	
Winfield Locks K 31.1	175*	91*	130*	35*	118*	130*	49*

* Typical or sweet coal gas napthalene odor.

† H_2S odor.

‡ Sweet chemical odor.

average water threshold had dropped to about 39. The results at the Saint Albans Bridge, however, show a decided increase and change of odor threshold over that prevailing at the Patrick Street Bridge; and the so-called sweet coal gas naphthalene odor prevailing in this section of the river carries down to the Winfield Locks without much decrease in threshold intensity.

The data listed in this table were sufficient to indicate that the sweet coal gas naphthalene odor which was causing the water plant treatment troubles had its origin in the South Charleston industrial area.

In order to locate the objectionable effluents in the South Charleston area, arrangements were made with the plant executives of all the plants involved to take at least one sample from every effluent of appreciable size in the whole area. When the survey was completed 44 industrial effluents in the South Charleston area had been sampled and some of these had been sampled many times. Two industrial effluents in the Nitro area were sampled, but no great amount of work was done there since its industrial section did not contribute materially to the river odor load.

After some work had been completed on the industrial effluents, it began to appear that, of the industries in the area, Plant B was responsible for most of the high river odor. Since the other plants in the area were evidently not contributing greatly to the odor problem, the analyses from these plants will be omitted from this paper.

Table 4 lists the principal effluents from Plant B, together with the type and intensity of odors present in each. Observation of the table will indicate that Effluents 2 through 10 had sweet-fruit-alcohol odors, and that Effluents 11 and 19 had coal gas naphthalene odors of high intensity. When examinations of the river were made, it was found that the coal gas naphthalene odor from Outfall 19 spread out fan-wise, going down stream until it spanned the whole channel of the river. In contrast with Effluent 19, the coal gas naphthalene odor from Effluent 11 did not impart much odor to the river, indicating that the discharge from this outfall was small. That this was true was confirmed by the plant management and, thus, the outfall was eliminated as a source of consequential river odor.

Since the odor downstream was sweet coal gas naphthalene in nature, it seemed reasonable to assume that the sweet odor from the seven outfalls mentioned was combining, in the river, with the coal gas naphthalene odor from Outfall 19 to form the objectionable downstream odor. The plant was therefore requested to attack its effluent odor problem by making an effort to correct the worst discharge, the one through Outfall 19, and to improve the lesser offenders yielding sweet-alcohol discharges.

On about February 1, 1941, the management of Plant B, after encountering some difficulty in obtaining equipment, placed in operation a new recirculation system, which recycles the objectionable part of the effluent originally passing through Outfall 19. Since the new unit was placed in operation, a considerable number of check threshold determinations have been made on this discharge; and they

have indicated that the average coal-gas-naphthalene threshold is now 250. This figure represents a definite improvement over the original average threshold of 15,230.

TABLE 4

Three Analyst Average Threshold Odor Results for Plant B Effluents

EFFLUENT NO.	FIRST SAMPLING PERIOD			SECOND SAMPLING PERIOD			GRAND AVERAGE THRESHOLD
	Threshold	Type	Date	Threshold	Type	Date	
2	500	Sweet Fruit	2/23/40	716	Sweet Fruit	2/29/40	
2	3,567	Sweet Alcohol	3/16/40				1,595
2	2,891						2,891*
3	967	Sweet Ester	2/23/40	46	Fruit Ester	3/ 6/40	510
4	717	Alcohol	2/21/40	2,850	Fruit Ester	3/ 6/40	1,780
8	1,830	Alcohol	2/21/40	667	Ester	3/ 6/40	1,250
9	3,000	Oil Refinery	2/21/40	5,750	Naphtha Oil Refinery	3/ 8/40	4,375
10	1,400	Alcohol	2/21/40	475	Alcohol Ether	3/ 5/40	940
11	5,250	Coal Gas Naphthalene	2/23/40	19,100	Coal Gas Naphthalene	2/26/40	
11	6,500	Coal Gas Naphthalene	3/ 8/40				10,280
14	1,700	Wax	2/23/40				1,700
16	400	Alcohol Ester	2/19/40	1,020	Varnish Lacquer	2/26/40	
16	1,050	Almond Ester	3/ 5/40				820
18	2,417	Coal Gas Rosin	2/19/40	4,967	Oil Rosin	2/26/40	
18	2,750	CH_2, H_2S	3/ 5/40				3,380
19	5,433	Coal Gas Naphthalene	2/29/40	19,000	Coal Gas Naphthalene	2/19/40	
19	17,500	Coal Gas Naphthalene	2/23/40	18,000	Coal Gas Naphthalene	2/26/40	
19	16,200	Coal Gas Naphthalene	3/ 5/40				15,230
19	7,221	Coal Gas Naphthalene					7,221*

* Average of 5 daily composites, 1937–38.

Since the installation of the new equipment, a close observation of the water pumped into the plant at Nitro has indicated that, after the water carrying the bad odor had been given an opportunity to flow out, only small quantities of the coal gas naphthalene odor have been present in the river.

Elk River Survey

The Elk River Survey, made between December 7, 1939, and January 28, 1940, covered a highly industrialized gas and oil area on the river proper, extending from the Queen Shoals highway bridge to the mouth of the stream, a distance of about 25 mi. (Fig. 1).

Table 5, prepared from the West Virginia Water Service Company's monthly operating forms for the city of Charleston, demonstrates the increase in quantity of carbon fed between 1933 and 1939, a measure of the increase in odor troubles at the Charleston plant.

Before discussing the lower river proper, the fact that no appreciable quantities of odor were present in the larger tributary creeks of the lower Elk Basin should be pointed out. Table 6 evidences

TABLE 5

Carbon Fed at Charleston Water Plant as Taken From West Virginia Water Service Company Report Forms

YEAR	CARBON FED	AVERAGE DAILY CARBON USED
	lb. per yr.	*g.p.g.*
1933	1,715	0.0066
1934	9,485	0.0336
1935	3,550	0.0123
1936	60,770	0.169
1937	14,300	0.0214
1938	54,600	0.135
1939	79,290	0.212

this lack of odor from the tributaries and will serve to indicate that the odor was coming from industries on the main stem of the river.

Frequent river sampling during December and January indicated that the highest odor threshold occurred, as a general rule, at the Clendenin Bridge and that the odor tapered off progressively down to the Charleston intake. In Table 7 have been listed the average weekly odor analyses and Saturday odor analyses for the Elk River during the month of January. This table shows clearly that, on some of the Saturdays listed, a change from a natural gas to an oil odor took place in the river water between the Falling Rocks bridge and a point 1.5 mi. below. A change similar to this was also noted at times in some of the analyses on other days.

Further, Table 7 indicates that on three Saturdays in January a marked increase in odor threshold over the Falling Rock figure, took

TABLE 6

Three Analyst Average Threshold Odor Results at Mouth of Elk River Tributaries, December, 1940

SAMPLING POINTS	NUMBER OF SAMPLES AND DATE TAKEN							AVERAGE THRESHOLD
	1	2	3	4	5	6	7	
Mouth, Big Sandy	1	1	1	1	1			1
	12/12	12/18	12/20	12/21	12/27			
Mouth, Blue Creek	2	1	4	4	3	5	3	3
	12/4	12/5	12/12	12/18	12/20	12/22	12/27	
Mouth, Little Sandy	0	0	2	1	1	3	1	1
	12/4	12/5	12/15	12/19	12/21	12/26	12/28	
Mouth, Coopers Creek	1	2	0	1	1			1
	12/15	12/19	12/21	12/26	12/28			

TABLE 7

Three Analyst Average Threshold Odor Results—Elk River, January, 1940

SAMPLING POINTS	SATURDAY 1/6	WEEKLY AVE. 1/2 THROUGH 1/6	SATURDAY 1/13	WEEKLY AVE. 1/8 THROUGH 1/13	SATURDAY 1/20	WEEKLY AVE. 1/16 THROUGH 1/20	SATURDAY 1/27	WEEKLY AVE. 1/22 THROUGH 1/28
Turner Station		2	1	1	1	1	1	1
Clendenin Bridge	77	75	51	37	19	13	35	37
1.6 Mi. Above Falling Rock	90	160	61	55	18	11	19	40
Falling Rock Bridge	107	52	28	65	10	7	27	27
1.5 Mi. Below Falling Rock Bridge	122*	52	45*	38	12	10	21	26
Blue Creek Bridge	145*	56	36*	27	10	10	39*	18
Elkview Bridge	26	27	40*	24	6	9	92*	30
Big Chimney Bridge	29	22	23*	20	6	6	13	11
Coonskin Intake	10	10	14	12	4	4	10*	8
Discharge, Queen Shoals, *sec.ft.*	162	199	185	165	594	1,049	266	360

* Indicates gas and oil odor; all others were natural gas odors.

TABLE 8

Water Odor and Carbon Fed at Charleston as Taken From the Operation Report of the West Virginia Water Service Co.

DATE	DAY	CARBON FED DAILY		WATER PLANT RAW WATER THRESHOLDS*	RIVER DISCHARGE QUEEN SHOALS
		lb.	*g.p.g.*		*sec.ft.*
January 5	Fri.	490	0.48	8–G†	172
" 6	Sat.	455	0.46	8–O†	162
" 7	Sun.	595	0.76	8–O	144
" 8	Mon.	875	0.80	30–O	158
" 9	Tues.	595	0.55	25–O	168
" 13	Sat.	676	0.68	16–O†	185
" 14	Sun.	766	0.86	16–O	428
" 15	Mon.	832	0.85	24–O	960
" 16	Tues.	780	0.79	10–O	1,230
" 21	Sun.	455	0.48	4–O	538
" 22	Mon.	420	0.41	8–O	428
" 23	Tues.	420	0.40	4–O	378
" 24	Wed.	420	0.42	5–O	418
" 27	Sat.	455	0.44	6–O†	266
" 28	Sun.	490	0.47	5–G	229
" 29	Mon.	840	0.86	20–O	206
" 30	Tues.	850	0.78	4–O	215
December 16	Sat.	350	0.36	8–G	679
" 17	Sun.	350	0.42	8–G	559
" 18	Mon.	490	0.52	16–G	492
" 19	Tues.	560	0.54	10–G	456
" 20	Wed.	630	0.67	5–G	544
" 24	Sun.	455	0.59	10–O	1,110
" 25	Mon.	525	0.65	10–O	836
" 26	Tues.	735	0.78	4–O	644
" 27	Wed.	595	0.63	5–O	517

* "G" indicates natural gas odor; "O," oil odor.

† Analyses showed strong oil odor below Falling Rock.

place in a section of the river below Falling Rock. This condition was considered unusual because the weekly average thresholds showed no tendency for the odor to increase below Falling Rock. These results were taken to indicate that Plant A, located at Falling Rock, was discharging an effluent on Friday evening or early Saturday morning which imparted a strong oil odor to the Elk River.

Table 8 was prepared from the operating reports of the West Virginia Water Service Co. for its Charleston plant. This table lists the quantity of carbon fed and the odor threshold recorded at the water plant for four periods in January and two in December. It is evident that an increase in odor took place together with the increase in carbon fed on five of the six Mondays listed. By comparing Table 7 and Table 8, it will be noted that on three of the Saturdays just preceding the Mondays mentioned above, an increase in odor threshold was found in the river below Falling Rock. On the other Saturday in January no odor increase was found in the river below Plant A, and no increase of odor or carbon took place at the water plant on the following Monday. No river results are available on the Saturdays preceding the Mondays with odor increases in December.

Mention should probably be made of the fact that the river data were obtained by the organization listed earlier in this paper and the water plant intake data by water plant personnel; and that, therefore, there was no exchange of data, the relationship between the two groups being established months after the river survey had been completed.

These results just reviewed seemed to establish the fact that Plant A was the source of odor trouble, so a copy of the Elk River report, setting forth the findings, was sent to the plant. The report also recommended that the plant segregate all direct contact waters and recirculate or provide treatment for these wastes before discharging them to the stream.

It was obvious from the study that an appreciable quantity of odor was entering the Elk River between the Queen Shoals Bridge and the Clendenin Bridge. In order to obtain some information concerning the source and extent of this river odor, a more detailed study was made of the section of river between these two points.

In contrast to the oil odors below Falling Rock, most of the odors in the Clendenin section of the river were natural gas in nature. Table 9 shows that there was no appreciable odor in the river above

the Cobb Station industrial area. A considerable quantity of odor is apparent, however, just below the industrial area and at the right quarter point opposite the water plant intake. It will also be noted that no large quantity of odor was present during the survey period in the Clendenin intake. The fact that this odor band sticks to the right side of the river until it flows below the Clendenin intake indicates why Clendenin does not have serious odor troubles except during periods of low river flow.

TABLE 9

*Three Analyst Average Threshold Odor Results in Elk River Above Clendenin**

ELK RIVER SAMPLING POINTS	JAN. 2	JAN. 3	JAN. 4	JAN. 5	JAN. 6	JAN. 8	JAN. 9	AVERAGES	ABOVE CLENDENIN BRIDGE
									mi.
Queen Shoals Bridge	2	1	2				2†	2	4.8
Turner Station								1‡	3.6
⅛ Mi. Below Cobb Station Industrial Area								1500§	3.0
Opposite Clendenin Water Plant Intake	157	166	435	272	190	91	32	192	1.3
Clendenin Water Plant Intake	12	7	5	14	17	2	2	8	1.3
Clendenin Bridge—Right bank	85	56						70	0.0
" " —Center			112	62				87	0.0
" " —Left bank	75	35						55	0.0
" " —Composite					77	20	6	34	0.0
Queen Shoals Discharge, *sec.ft.*	278	200	185	172	162	158	168	189	

* All odors are natural gas in nature.

† Average of 13 sampling dates in December, 1939.

‡ Average of 13 sampling dates, January 11 to 27, 1940.

§ Sample taken January 10, 1940.

The work done in the upper section of the river seemed to indicate that a natural gas odor of considerable proportions, having its origin in the Cobb Station industrial area, was flowing downstream to combine with and complicate the odor present in the lower river area. Copies of the Elk River report were therefore sent to both plants in the Cobb Station industrial area and the plant managements were requested to comply with the recommendations that they segregate their direct contact wastes and either recirculate or treat these wastes before discharging them into the river.

Some resurvey work on the Elk River industries was carried out by state and federal personnel during the winter 1940–41. The main object of this work was to assist the plant executives in the location of the unit wastes leaving their plants, which were responsible for the objectionable odor belts in the river. The resurvey served to indicate that discharge odors had already been improved at one of the plants and, further, to label the bad effluents at the other two plants. As a result of this recent work, the executives from the plants have a clearer conception of which effluents are troublesome and, by concentrating on these, will be able to effect additional river odor improvements in the near future.

Summary

In summarizing the information presented in this paper, the following points are of particular importance:

1. A marked increase in raw water odor has taken place at several town intakes in the Charleston area, in recent years, as is demonstrated by a carbon-feed increase of 10-fold at Nitro, 120-fold at St. Albans and 32-fold at Charleston.

2. The Kanawha River survey served to establish the fact that most of the downstream odor had its origin in a plant in the South Charleston industrial area.

3. The Elk River survey demonstrated the fact that two serious odor belts exist in the Elk River as a result of the discharge from three industrial plants.

4. Recommendations covering a reasonable way of treating these industrial wastes for odor removal were made to the offending industries by the State Department of Health.

5. Two offending industries already are operating waste remedial units, and the others are expected to co-operate with the Health Department by inaugurating effluent improvement programs in the near future.

The author wishes to take this opportunity to express the appreciation of the personnel of the West Virginia Department of Health to the United States Public Health Service, to the West Virginia Water Service Company and to the many industries involved for their earnest co-operation and assistance, which contributed much toward making these surveys successful.

Two Groups of Flagellated Algae Serving as Indicators of Clean Water

By James B. Lackey

IT has long been recognized that there is a definite relationship between the sanitary condition of any given stream section and the organisms living in that section. This relationship is fairly well known for the larger free-swimming or attached animals. Such a relationship also applies to the microscopic creatures whether living on or attached to the bottom, or composing the assemblage of suspended forms known as rheoplankton.

Whipple, Fair and Whipple (1) have summarized the findings of a number of workers and have classified the organisms as to degrees of pollution preferred by them. Such a classification of indicator organisms can be very useful to workers with water supplies, especially if it includes a sufficiently large variety of organisms so that some might reasonably be expected to occur in almost any sample taken at any time.

Taking a sample which might contain animals as large as fish or shellfish may not be feasible, but where equipment includes a microscope or access to one, a small sample is easily taken and its microscopic life can either be concentrated by centrifuging, or killed by adding enough formalin to make a 3 per cent solution in which the organisms gradually settle and can be concentrated by decantation. In reservoirs and large streams or streams issuing from lakes, some microscopic forms are found at almost every season of the year. Flood conditions, or excessive turbidity may decrease plankton until no information will be available, but larger forms will likewise disappear under such conditions. If a small stream is under investiga-

A contribution by James B. Lackey, Cytologist, U. S. Public Health Service, Stream Pollution Investigations Station, Cincinnati, Ohio.

tion, samples of the bottom film will give the most information as to the animals present. Unfortunately, we have scant knowledge of the sequence of bottom-dwelling microscopic forms occurring in the transition from foul to clean water. It would seem that the plankton organisms represent the most accessible, most widely known and most easily worked-with group.

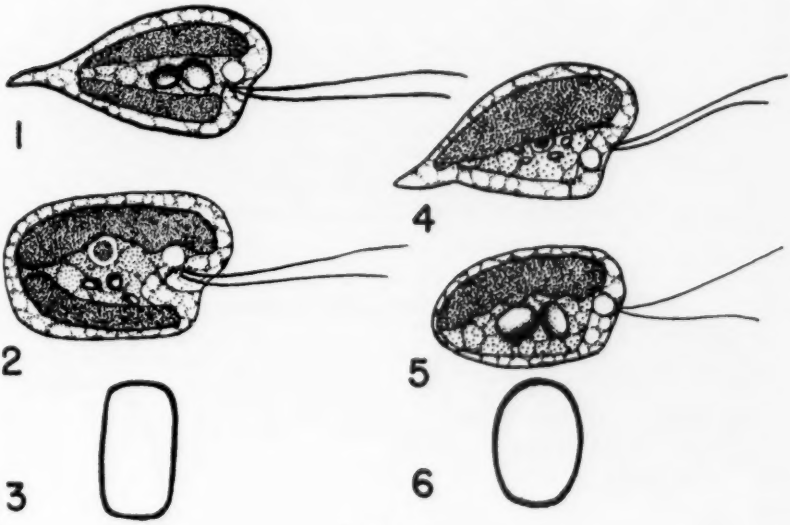
We have recently been forced to the conclusion that relatively few plankton organisms show clear-cut responses to pollution or its absence. This lack of response appears to be particularly true of the Euglenidae (2) when considered as a group, and applies also to the Volvocales. Certain individual species of Euglenidae and Volvocales appear to favor sewage laden water, others favor clean water, and some species appear to be widely tolerant. Two classes of algae, the olive-green flagellates, or Cryptophyceae, and the yellow-green flagellates, or Chrysophyceae, however, have been found to react, as a group, adversely to pollution. They seem to be indicators of clean, unpolluted water if they are present in moderate or great abundance. Both of these classes are composed of small flagellates, most of which are known only to biologists. Five genera—*Cryptomonas*, *Mallomonas*, *Synura*, *Uroglenopsis*, and *Dinobryon*—however, are common, and are cited by Whipple, Fair and Whipple (1), Hale (3), and others as causing trouble in water supplies.

The Cryptophyceae

The Cryptophyceae are adequately described, in German, and figured by Pascher and Lemmermann (4), and to a lesser extent, in English, by Fritsch (5); the Chrysophyceae are also described by these writers as well as by the American writer Smith (6). *Synura*, *Dinobryon* and *Uroglenopsis* (*Uroglena* in Hale and Whipple) are colonial forms, large and easily recognized. They are figured by Whipple, Fair and Whipple (1) and Hale (3), but the smaller forms are difficult until they have been recognized the first time.

Very detailed observations have been made as to the occurrence of the Cryptophyceae and Chrysophyceae in clean and polluted water in the Ohio River valley. These observations cover more than four years study and represent an intensive survey of the Scioto River in foul, transitional and clean stretches, surveys of other river systems, and random sampling of many streams above and below known points of sewage pollution. The conclusions presented herein are largely based on the Scioto River studies with supporting evidence from other sources.

Six genera of plankton Cryptophyceae have been found in the Ohio Valley. Two of these, *Chilomonas* and *Cyathomonas*, are colorless, and not important as constituents of the rheoplankton. *Protochrysis* is green, but has been very rare. *Chroomonas*, very common at times, is bright blue, quite small and very active. There are four or five species but only three (Figs. 1–3) have been abundant in samples studied. None of these retain recognizable characters after formalin preservation, so that they can be studied only in fresh samples. Furthermore, their small size and activity makes them very difficult even then.



FIGS. 1–6

FIG. 1. *Chroomonas nordstetii;* lateral view
FIG. 2. *Chroomonas setoniensis;* lateral view
FIG. 3. *Chroomonas setoniensis;* cross-section
FIG. 4. *Rhodomonas lacustris;* lateral view
FIG. 5. *Rhodomonas lacustris;* variant
FIG. 6. *Rhodomonas lacustris;* cross-section

The genus *Rhodomonas* (Figs. 4–6) is represented by one species, *R. lacustris*. It likewise is of small size, and in shape resembles *Chroomonas*, but is more variable. Its color shades from pale brown to olive green, and after formalin preservation bleaches to a pale green. Figure 7 shows its average distribution in the Scioto River. The genus shows a clear cut response by decreasing greatly in the polluted water and increasing rather slowly as the water recovers,

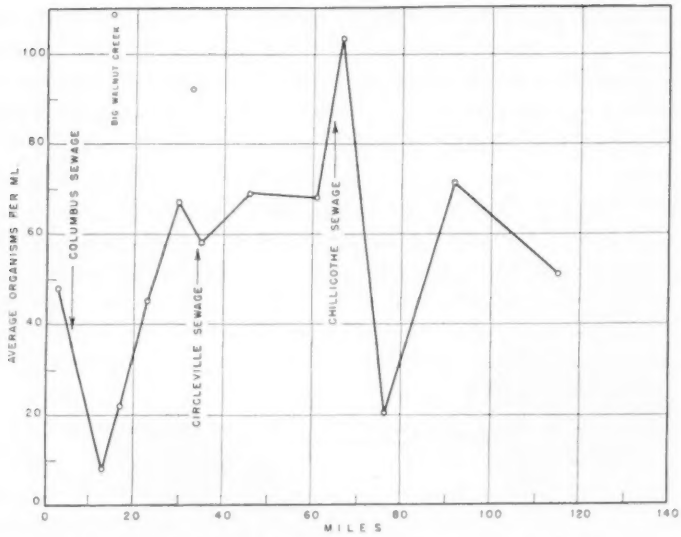
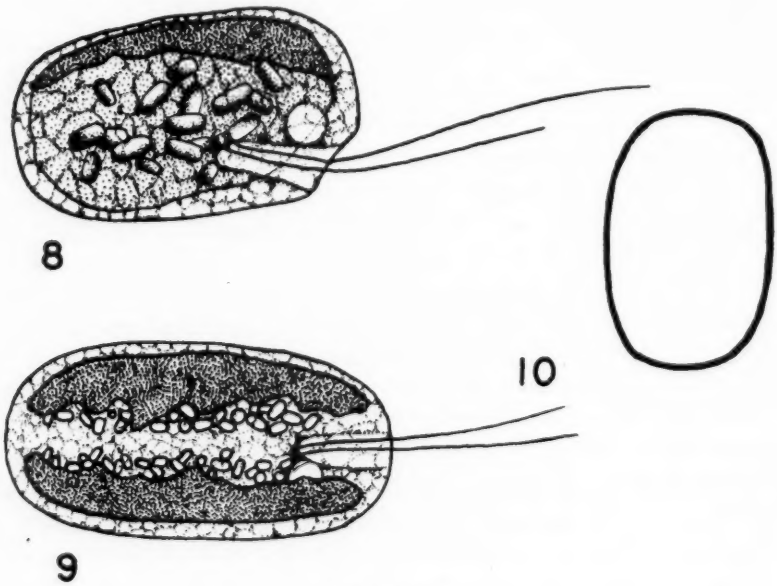


FIG. 7. Average distribution of *Rhodomonas lacustris* in Scioto River of Ohio



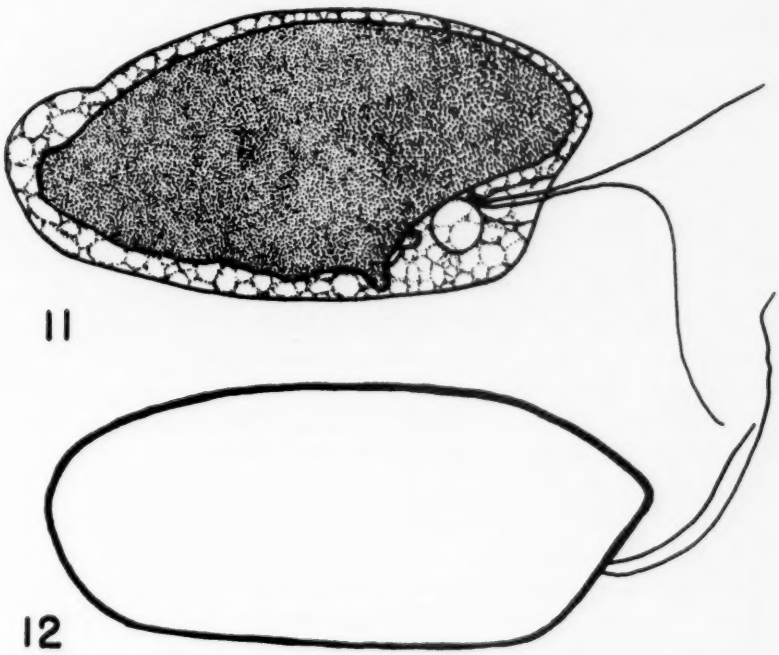
FIGS. 8–10

FIG. 8. *Cryptomonas erosa;* lateral view

FIG. 9. *Cryptomonas erosa;* vertical view

FIG. 10. *Cryptomonas erosa;* cross-section

even when large numbers are added to the river by Big Walnut Creek. Walnut Creek is a comparatively pure tributary of the Scioto, entering at Mile 15. Its flow may approximate two-fifths of the river flow, and since the average number of *Rhodomonas* contributed by it is 108 per ml. (circle near top in Fig. 7), the decided upward trend of *Rhodomonas* from Mile 15 to Mile 25 can be partly ascribed to the influence of this entering stream. In every case where the organism has been found in quantity above a source of pollution, it has shown a



FIGS. 11–12

FIG. 11. *Cryptomonas ovata;* lateral view
FIG. 12. *Cryptomonas ovata;* cross-section

drop or extinction in the polluted water. The reason we do not consider *Rhodomonas* as a prime indicator organism is because of its small size and the fact that, preserved, it might be confused with other microscopic forms. To a specialist, however, it is entirely adequate for such use.

The one remaining genus, *Cryptomonas,* contains several species, but all Ohio Valley forms have been referred to two, *C. erosa* and *C. ovata.* These two (Figs. 8–12) are readily recognizable when they

are alive. They are frequently abundant and occur during most of the year. While they are badly distorted by formalin preservation, they can nevertheless be identified and counted. Figure 13 shows the occurrence of the above two species in all samples taken from the Scioto River during 1937–38. It appears that they reach their greatest numbers in clean water; that their numbers decrease greatly in foul water, but may increase materially in the transition zone. Finding large numbers of *Cryptomonas* in a sample apparently indicates good sanitary quality in a water or that it is from a zone in which rapid recovery is taking place.

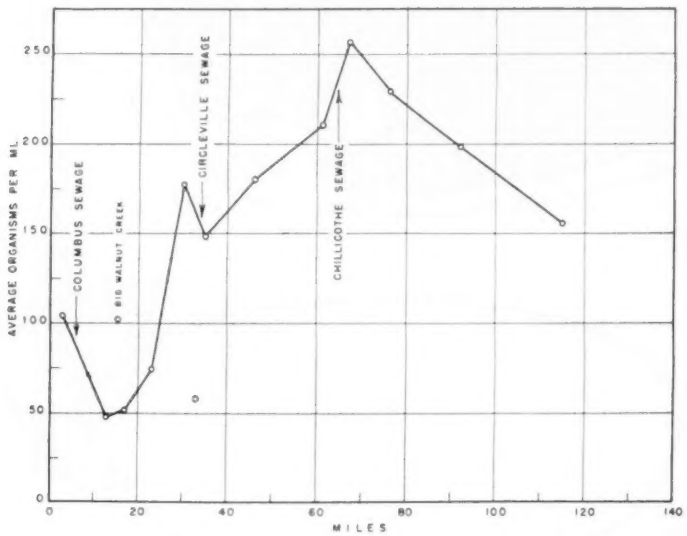


FIG. 13. Average distribution of *Cryptomonas* in Scioto River of Ohio

The Chrysophyceae

Thirteen genera of Chrysophyceae, comprising 25 or more species have been found in the Ohio watershed. Considering the large number of samples (884) and the abundance of the organisms during much of the year, their occurrence in the Scioto River is looked upon as typical. With one exception, they are found to be abundant in clean water; they show a very sharp decrease in foul water, and recover but slowly in water which is gradually becoming purified below a sewer outfall. These Chrysophyceae, or at least those species

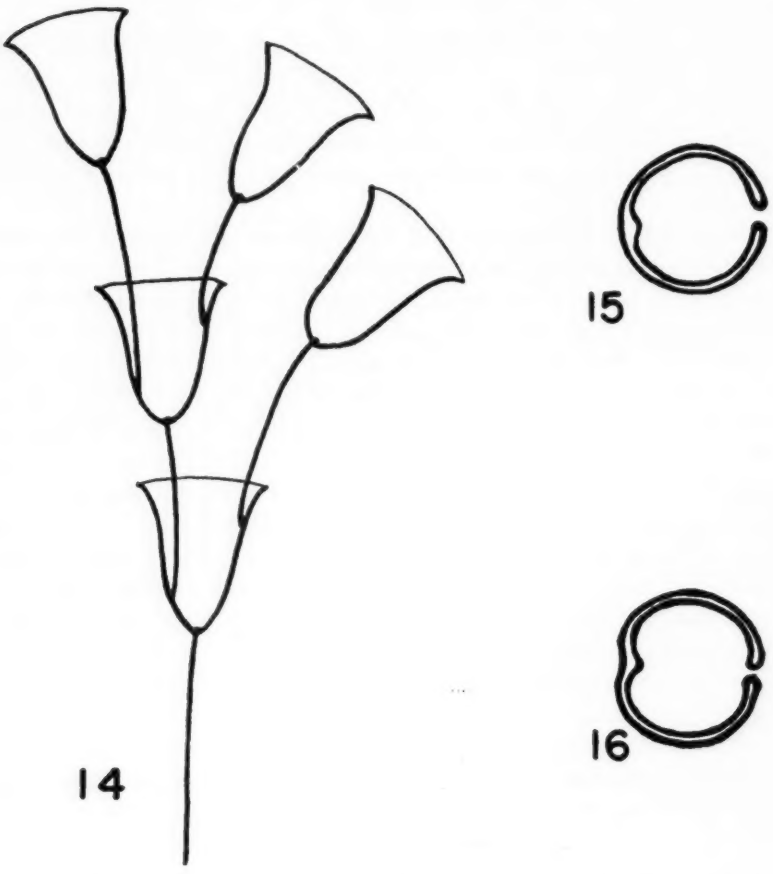
referred to herein, should be valuable indicators. The more common ones, except *Mallomonas*, *Synura* and *Uroglenopsis* are well preserved by formalin; their characteristics are clear cut; their color is distinctive; and the movements of the living ones are generally slow and deliberate.

The only Chrysomonad which has occurred in foul water more commonly than in clean water is a colorless form, *Physomonas vestita*, which has been somewhat abundant in the distillery waste laden waters of Tanner's Creek, a small tributary of the Ohio below Cincinnati. Since its occurrence has been rare, it is not further discussed.

Dinobryon is perhaps the best known, most easily identified member of this group. In lakes and ponds it sometimes attains an enormous abundance; in smaller streams, such as the Scioto, its numbers may be much less. Since all species of the genus have been found to react alike, the layman need concern himself only with recognition of the genus. Ahlstrom (7) has recently published an excellent illustrated key to the nine species and two varieties found in the United States, in which it is shown that essential differences are in shape, length, contour and method of branching of the shell; any species is easily recognized as belonging to the genus *Dinobryon*. Numbers of this genus have at times been high in the Scioto River in the unpolluted region above the entering Columbus sewage, but there has been an invariable decrease, sometimes a total extinction, in the sewage laden stretch, and a gradual increase, sometimes to quite large numbers, far downstream where the water is clear and of good sanitary quality.

No other living organism is easily confused with *Dinobryon*, although the empty colonial shells of *Poteriodendron petiolatum* (Fig. 14) somewhat resemble those of *Dinobryon*. They, however, are not so long, are more rounded basally, and have a thicker base. They are also inserted by means of a stalk instead of being directly attached. The living organism is colorless and quite unlike *Dinobryon*. This organism has been very abundant in the aeration chambers of the new Columbus (Ohio) sewage treatment plant. The writer knows of only one reference to the finding of *Dinobryon* in foul water; Tomlinson (8) reported it from a milk purification plant in England. All other indications are that it is a clean water organism.

One Chrysomonad, *Chrysochromulina parva*, is too small, too active, and too poorly preserved by formalin to be useful. The genera *Chromulina*, *Chrysamoeba*, *Chrysapsis*, *Chrysopyxis*, *Hymenomonas*,

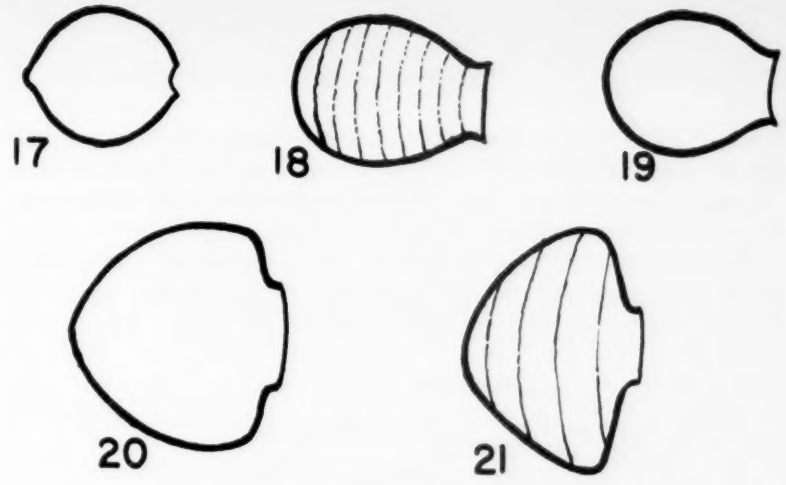


FIGS. 14–16

FIG. 14. *Poteriodendron petiolatum;* colony of empty shells; common to some sewage polluted waters

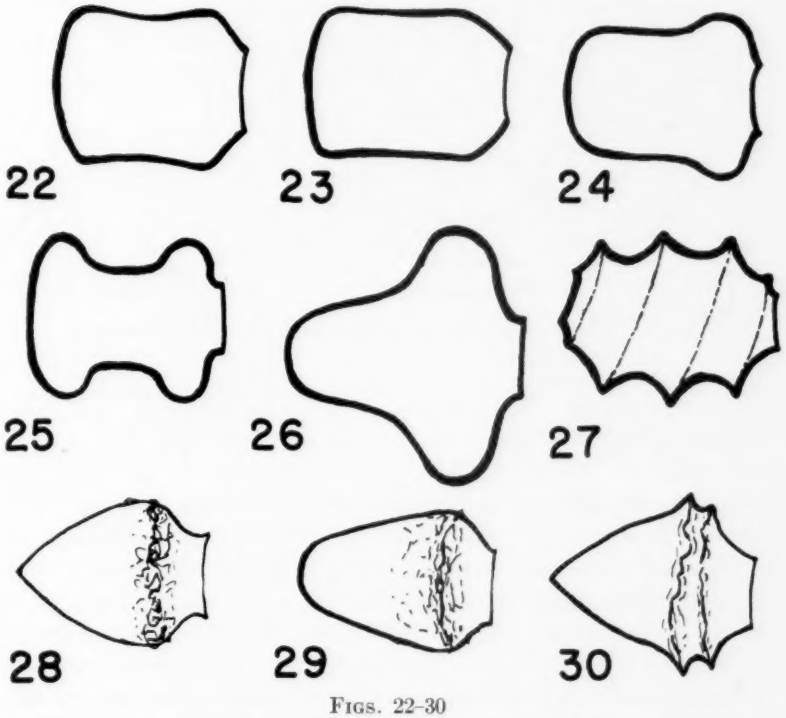
FIGS. 15, 16. *Chrysococcus rufescens;* optical sections through typical shells of species

Lagynion and *Oochromonas* have occurred too seldom to be of interest to the layman, although some of the findings relative to them are of considerable biological interest. *Synura* has appeared only in very small numbers and on very few occasions in the Scioto River. This



FIGS. 17–21

FIG. 17. *Chrysococcus rufescens;* shell shape
FIGS. 18, 19. *Chrysococcus ovalis;* shells
FIGS. 20, 21. *Chrysococcus hemisphaerica;* shells



FIGS. 22–30

FIGS. 22–25. *Chrysococcus cylindrica;* variation in shell types of species
FIG. 26. *Chrysococcus amphora;* shell
FIG. 27. *Chrysococcus spiralis;* shell
FIGS. 28–30. *Chrysococcus aspera;* shell types

has been rather surprising in view of its abundance as noted by Kofoid (9) in the Illinois River. It has occurred in abundance in three creeks tributary to the Ohio below Cincinnati, and for long periods, but only in the unpolluted sections of these creeks.

Chrysococcus is referred to sparingly in the literature. Five species are treated in Pascher and Lemmermann (4) and three of these have been found in the present study. The type species, *C. rufescens*

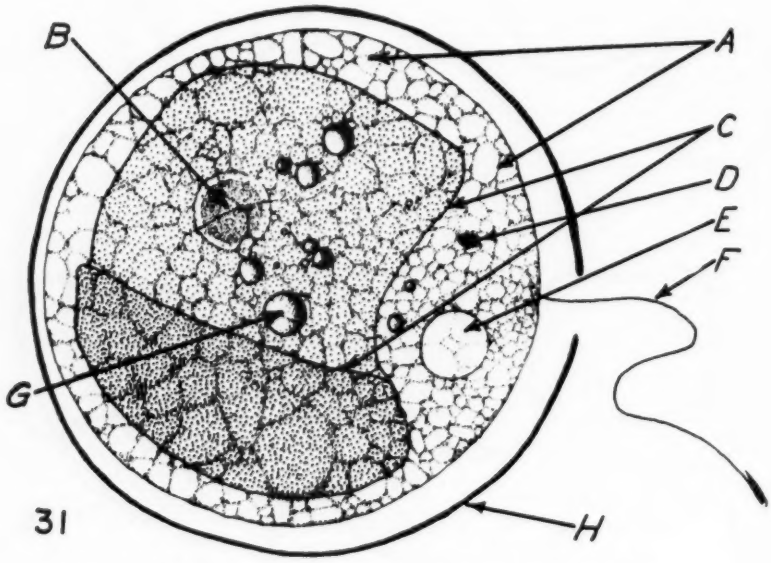


FIG. 31. *Chrysococcus major;* optical section showing structure:

A. Cytoplasm
B. Nucleus
C. Large folded-over chromatophore
D. Eyespot or stigma
E. Contractile vacuole
F. Flagellum
G. Oil droplets
H. Relatively thin shell

(Figs. 15, 16) has been by far the most abundant, but the writer (10, 11) has described seven additional Ohio Valley species of which all but two have been numerous (Figs. 17–31). These species are all excellently preserved by formalin and never become coated with debris, as sometimes happens to *Euglena*, *Cryptomonas* and others. Identification is easy with some study and by reference to figures. It should be a simple matter for even an inexperienced microscopist to note a minute, sharply differentiated, round or egg-shaped, deep

brown, slowly swimming or motionless body, and to be able to determine that he is looking at a *Chrysococcus* and not a pollen grain or some unidentifiable organism.

The average distribution of *Chrysococcus rufescens* in the Scioto River is shown in Fig. 32. Its numbers are high (105 per ml.) in the clean water at Mile 3, four miles above the entering Columbus sewage. At Mile 13, in the foul water zone, population has decreased to 25 per ml., and on many occasions numerous empty shells and shells containing dead organisms have been found here. At Mile 15, as

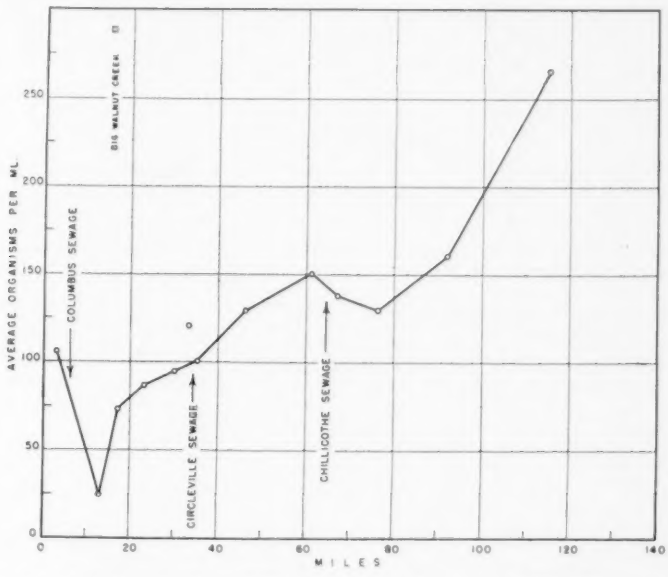


FIG. 32. Average distribution of *Chrysococcus rufescens* in Scioto River of Ohio

shown by the circle in the upper left of Fig. 32, Big Walnut Creek adds an average population of 313 per ml. to the river, so the river population at Mile 17 rises to 74 per ml. As the river slowly recovers, this population rise continues to Mile 33, at Circleville, where there is an average of 120 per ml. This is indicated by the circle just above the line; it was not included in the graph because of the smaller number of samples taken there. The rise reaches Mile 60, at Chillicothe, where a slight decline sets in, probably due to Chillicothe sewage. Subsequently, the peak of 260 per ml. is reached at Mile 115 where the river is a sparkling clean stream. Here, then,

is an organism which, whenever encountered in large numbers, serves excellently as an indicator of clean water.

A figure similar to Fig. 32 could be charted for the entire genus or for any other species of *Chrysococcus*. If anything, the reduction in numbers at and just below Shadeville (Mile 13) is even more pronounced for other species of the genus, and investigation of points above and below entering sewage has shown substantially the same behavior in other streams, such as the Miami Rivers, the Licking, and a number of smaller creeks. In short, the Cryptophyceae as a whole, and the Chrysophyceae as a whole; or certain genera of these groups, such as *Cryptomonas* or *Dinobryon* or *Chrysococcus*, are easily identified organisms which, when abundant, are characteristic of clean water.

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Nomograph for Determining Dissolved Oxygen Concentration in Water

By W. D. Hatfield

THE table "Solubility of Oxygen in Fresh and Salt Waters" given in *Standard Methods** is of limited use, because many of the streams in the southern area of the United States have summer temperatures between 30° and 50°C., which temperatures are above those given in the table, and because corrections for barometric pressures other than those at sea-level must be made by equations given below the table. A suggestion that the table be extended to 50°C. led to a study of the possibilities of replacing it with a nomograph which would include pressure, temperature and salinity corrections. Such a nomograph (Fig. 1) has been prepared as described in this paper.

The partial pressure of oxygen in the atmosphere equals 20.9 per cent of the barometric pressure corrected for the vapor pressure of water at the given temperature and relative humidity. If this quantity is substituted in the equation representing Henry's law, we obtain:

$$\text{p.p.m. } O_2 = \frac{0.0372(P - u)}{K_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which P is the barometric pressure in millimeters of mercury; u is the aqueous vapor pressure in millimeters of mercury; and K_t is the constant for a given temperature as given in the *International Critical Tables*.† If these values of K_t and t°C. are plotted on cross-

A contribution by W. D. Hatfield, Superintendent, Sanitary District of Decatur, Ill.

* *Standard Methods of Water Analysis.* American Public Health Association and American Water Works Association, New York (8th ed., 1936), p. 153.

† *International Critical Tables of Numerical Data, Physics, Chemistry and Technology.* National Research Council. McGraw-Hill, New York, (1928), Vol. III, p. 257.

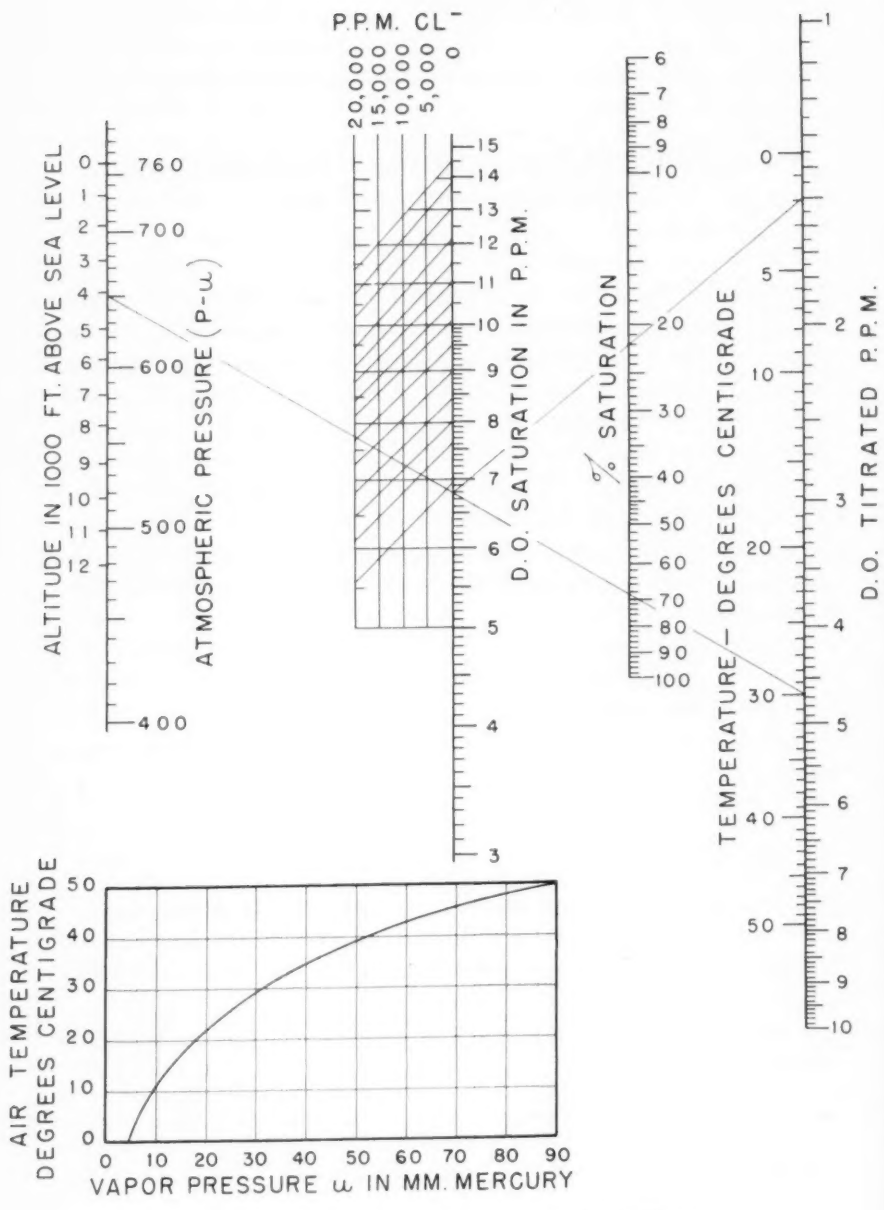

FIG. 1. Solubility of Oxygen in Fresh and Salt Waters

section paper, a straight line between 0° and 35°C. is obtained. Above 35°C. the constant K_t gradually decreases so that at 50°C. it is 4.44 instead of 4.54 as indicated by a straight line projected through the points from 0° through 35°C. The equation of the straight line is:

$$t^\circ = 18.1\ K_t - 34.7$$

or

$$K_t = \frac{t + 34.7}{18.1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and, substituting Equation 2 in Equation 1, we obtain:

$$\text{p.p.m. } O_2 = \frac{0.67(P - u)}{t + 34.7} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

In fitting Equation 3 to the data in the table in *Standard Methods* or in the *International Critical Tables*,* a still better fit is obtained by adjusting the constants to:

$$\text{p.p.m. } O_2 = \frac{0.678(P - u)}{t - 35} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

This equation may be expressed in the logarithmic form:

$$\log (\text{p.p.m. } O_2) = \log 0.678(P - u) + \log \left(\frac{1}{t - 35}\right) \quad \ldots\ldots (5)$$

in which form it is easily placed in a nomograph using single cycle 20-inch logarithmic scales for the pressure $(P - u)$ and the temperature $(t - 35)$, and a single cycle 10-inch logarithmic scale located exactly equidistant between the other two scales and adjusted up or down so that it coincides with any two points located by calculation or by reference to the table in *Standard Methods*.

In this way the nomograph is provided with three scales from which the dissolved oxygen (D.O.) in parts per million may be read for any pressure and temperature likely to be encountered. For convenience the pressure scale is also scaled for altitude up to 12,000 ft. for use when barometric readings are not available. To the left of the D.O. saturation scale is a correction grill for saline waters. A corrected reading is obtained by starting with the straight edge reading on the D.O. saturation scale and following the correction

* *Ibid.*, Vol. III, p. 258.

line down and to the left to a point equivalent to the chloride concentration, and then horizontally back to the D.O. saturation scale.

The per cent saturation scale is placed equidistant between the D.O. saturation scale and the t°C. scale. The latter is scaled on the right side with a single-cycle inverted logarithmic scale from 1 to 10 to represent the D.O. titrated in the sample under consideration. The values on this scale may be considered to be 0.1 to 1.0, 1.0 to 10.0, and 10.0 to 100.0 with proper adjustment of the decimal place on the per cent saturation scale.

For example, in a titration of fresh stream water with a D.O. content of 1.5 p.p.m. at about 2,900 ft. above sea-level, with the barometer reading 682 and the stream and air temperature at 30°C. on a rainy day (humidity 100 per cent), the procedure is as follows: (1) at 30°C., u = 32 mm. and 682 − 32 = 650; (2) place straight edge on 650 (pressure scale) and on 30°C. (t°C. scale) and read 6.8 p.p.m. on the D.O. saturation scale; and (3) swing straight edge to 1.5 p.p.m. on the parts per million D.O. titrated scale and read the answer, 22 per cent saturation, on the per cent saturation scale. If the above titration were 15.0 p.p.m. instead of 1.5 p.p.m., the procedure would be the same except the answer would be the scale reading multiplied by 10, or 220 per cent supersaturation.

Present Practice in Pressure Correction

The correction of the atmospheric pressure for the aqueous vapor pressure has not been standard practice in sanitary analysis. The data in the table in *Standard Methods* are the solubility of D.O. at the given temperature when the atmospheric pressure is 760 mm. and when the atmosphere is saturated with water vapor, a condition not generally-found in actual practice. For example, the D.O. as given in the table for 30°C., 760 mm., and saturated water vapor is 7.63 p.p.m. If the nomograph is used, the straight edge would be placed between (760 − 32) on the pressure scale and 30°C. on the temperature scale and the saturation would be read 7.6 p.p.m. If the relative humidity was 50 per cent (or 16 mm. aqueous pressure) the solubility would be 7.75 p.p.m., and if the humidity was zero, the solubility would be 7.9 p.p.m. This comparison indicates the rather fictitious accuracy of the second decimal place in the table when applied to actual conditions at the time of the analysis. In the lower left hand corner of the nomograph is a curve from which the aqueous vapor pressures may be read for air temperatures from 0° to 50°C.

The problem resolves itself into a question of definition. Are we interested in the per cent of saturation at a so-called standard condition related to sea-level and 100 per cent saturation of aqueous vapor pressure or humidity or in the per cent of saturation which would be possible in a similar unpolluted water at the point of sampling and at the humidity generally prevailing in that location? *Standard Methods** quite definitely describes the procedure to comply with the first of these conditions, but follows immediately with the statement: "at elevations differing considerably from mean sea-level, and for accurate work, attention must be given to the barometric pressure, the *normal pressure* in the region being preferable to the specific pressure at the time of sampling." This statement almost describes the latter definition and would be more exactly stated if it read "normal pressure and humidity in the region, etc." From a practical point of view the correction for vapor tension makes a difference of about 0.1 to 0.3 p.p.m. in the D.O. saturation and a 1 to 2 per cent difference in the per cent saturation. For accurate work both the humidity and vapor pressure must be known. In the example given to illustrate the use of the nomograph, the effect of the humidity was about the same as that of increasing the altitude 1,200 ft., or from 2,900 to 4,100 ft.

Summary

1. A nomograph is given by which the D.O. saturation may be determined from 0 to 50°C. and in which the per cent saturation of the titrated sample is calculated. Corrections may be made for salt concentrations.

2. The effect of vapor pressure on D.O. is emphasized. At higher temperatures this factor is almost as important as the high altitude correction.

* *Standard Methods of Water Analysis*, p. 152.

Pollution Prevention in Distribution Systems in Britain

By E. G. B. Gledhill and A. W. H. McCanlis

THE question of the precautions to be taken to prevent pollution of potable water supplies has received very close attention in Britain during recent years. It is fully appreciated that every undertaking has its own particular problems based on local conditions and that these naturally vary, but it is hoped that some of the points enumerated in this article will prove of general interest.

The Sutton District Water Co. supplies a population of approximately 325,000 in a compact area of 40 sq.mi., the greater part of which lies within the London Metropolitan Police Area. The water is pumped from deep wells in chalk and softened below 9.0 g.p.g.* by the lime process. It is believed that the Sutton District Water Co. was one of the early water suppliers to institute the practice of sterilization of new mains in Britain, the system being started in 1932. At first, the sterilization was carried out by use of a chlorinated soda solution which was introduced into the main through a hydrant or ferrule connection by pouring it down a $\frac{1}{2}$- or $\frac{3}{4}$-inch standpipe provided with a funnel. The amount of soda solution used was calculated to give a concentration of about 10 p.p.m. chlorine in the section of main to be sterilized, but this strength was later increased. Experience has shown that this method did not permit an even distribution of the sterilizing liquid in the section of the main to be treated, particularly when the main had been laid on undulating ground. The method was therefore discontinued.

Portable chlorinators using liquid chlorine from cylinders are now used to sterilize all new mains. Heavily chlorinated water is in-

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* All values in gallons throughout this paper refer to Imperial gallons.

jected under pressure into the main. The pressure water supply for the injector is obtained from a small pump and tank attached to the chlorinator, or by means of a temporary service taken from the end of the main which is being extended. Sometimes, in the case of small mains, the whole of the water used for charging the main is passed through the injector, while in other cases a second temporary service is laid for charging the main.

The chlorination is continued while the main is being charged, and the water is run to waste through a hydrant or special tapping at the far end of the main, until a strong chlorine residual is obtained. The chlorinated water in the main is then left to stand for a minimum period of 4 hr., the quantity of chlorine used being between 40 and 100 p.p.m. As a rule the main is left full of chlorinated water overnight so that the retention period is actually about 10 to 24 hr. Following this, and before being put into service, the main is flushed through a hydrant or washout, or through a special tapping at the end of the main by means of the temporary service laid for charging purposes during chlorination. The flushing operation is performed following the retention period, without emptying the main. A bacteriological sample is taken and the quality of the water determined before the new main is finally connected to the existing distribution system.

Air Raid Damage

So far, in the case of water mains damaged by enemy action, the same procedure has been followed, the repaired main being sterilized by means of chlorination, using a portable chlorinator and liquid chlorine whenever a sewer is damaged in the same crater or adjacent thereto, or if pollution is in any way suspected. Existing ferrule connections and hydrants are used whenever possible for the injection of the chlorine and the subsequent running to waste, but, if these are not available, special tappings are made. Should pollution not be suspected, the main, provided it is under 12 in. in diameter, is not chlorinated, but in addition to following the standard procedure, described in a later section, chloride of lime is placed in the pipes and fittings in sufficient quantity to give 50 p.p.m. in 300 yd. of the main to be laid. The foreman of the repair crew is provided with a table giving the required measure of chloride of lime to be laid in the main as a powder or poured into the main as a cream, depending upon circumstances. The main is then slowly charged to

full pressure for ½ hr. as a pressure test, and during that time the available chlorine in the chloride of lime is given time to act. The main is then well flushed, in both directions wherever possible, for a total period of not less than ½ hr.

It may be of interest here to mention that as soon as possible after damaged mains have been isolated, pamphlets are distributed to the consumers whose services are connected to the damaged section of main isolated, informing them of the damage and advising them to boil any water obtained from taps in the premises, if used for drinking or culinary purposes, or, in the event of their being unable to boil the water owing to the failure of gas or electricity services or shortage of fuel, to sterilize it by use of chlorinated soda solution. In addition, the pamphlet informs consumers that until the supply is restored, water may be obtained from temporary standpipes, the positions of which are indicated to the local air raid wardens, or from tank wagons to be circulated in the area. Consumers are also advised of the precautions to be taken in respect of hot water systems.

Standpipes, hydrant outlets and water tanks are cleaned out with chlorinated soda solution before being brought into use. The health officers in the area of supply of the district are advised of the steps which have been adopted to maintain a pure and wholesome supply at all times; and they have co-operated in the scheme by agreeing to circularize all drug stores in their area, suggesting that they display in prominent positions sample bottles of chlorinated soda solution of the well-known proprietary brands, with an explanatory note as to their use for sterilizing water.

When the damaged main has been repaired it is either chlorinated or treated with chloride of lime, as previously described, according to circumstances, then well flushed; and, when it is ready to be put into use, the consumers concerned are asked to run their taps to waste for not less than ½ hr., and advised that water used for drinking purposes during the following six days should first be boiled. The consumers in the Company's area of supply are "water conscious" and are not unduly perturbed when advised to boil all water used for drinking purposes.

From each repaired main a bacteriological sample is taken as soon as possible after it has been brought back into service, but, in any case, soon enough for the quality of the sample to be ascertained before the expiration of the six days. Should the sample prove satisfactory, no further action is taken—the consumers boiling all drinking

water up to the end of the sixth day and then reverting to normal. If the sample is unsatisfactory, however, the consumers affected are requested to continue boiling all drinking water until the main has been resterilized and tested. "Follow-up" samples, generally after a lapse of a fortnight, are taken from all mains repaired after enemy action. Of the samples taken after the repair of damaged mains, only in the case of one main were the results not up to standard, requiring the main to be isolated and re-sterilized. Samples taken subsequently showed absence of *Esch. coli* in 100 ml.

Main Laying and Repairs

As stated above, all new mains are chlorinated and samples of water tested before they are put into commission, and all repaired mains are similarly treated, according to size and circumstances, except that they are put into commission before the results of the bacteriological examinations of samples have been determined. Appropriate records of these sterilizations and the results of samples, etc., are filed together for future reference. Special written instructions (see Appendix, p. 1122) have been issued to the foremen and jointers outlining the procedure to be followed in main laying or repair.

Each length of pipe, before being lowered into the trench, is placed on trestles or V-blocks and the whole internal surface of the pipe well swabbed out with strong chlorinated soda solution by means of a mop mounted on a long handle. After swabbing, the ends of the pipe are sealed by fixing a pipe stopper of the expanding type at each end. These stoppers are not removed until the pipe has been lowered into the trench and each end in turn is ready for jointing. All specials and valves are similarly treated. As far as possible in waterlogged ground, the level of any water in the trench is kept below the pipes by the construction of sumps and the provision of suitable pumps. In this manner the risk of pollution due to the entry of foreign matter into the pipes during main laying is reduced to a minimum.

The yarn puchased by the company for use in jointing has been found to contain a high bacterial population, including coliform types. Accordingly, all yarn used for jointing water mains is first sterilized in air-tight tins, which are opened only when the yarn is actually used on the job. A large number of tins is kept for this purpose, each containing 5 lb. of yarn, an amount which, in practice, has been found a convenient unit for an average job; but smaller tins are

available for minor repairs. Every jointer has two tins which are marked with his name and kept in the storeroom. Once a tin has been opened and all or some of the yarn used, it is filled again and resterilized before being returned to the storeroom for re-issue. Although conditions under which the yarn is used are recognized to be far from ideal, the use of sterilized yarn has been justified.

As a further refinement to this practice the tins contain a shallow tray with a perforated lid, inside which is kept a small quantity of chloride of lime so that the yarn will remain permeated with chlorine while in the tins. The use of leaded yarn or certain types of flexible joints also assists in eliminating possible pollution from this source.

As soon as conditions allow, it is proposed, as a further step, to require that all pipes and specials be supplied by the manufacturers with the ends suitably covered or otherwise plugged, so that the internal portions of the pipes may be kept reasonably clean during transit and storage, and that such plugs remain in position until replaced by the expanding stoppers after swabbing has been performed as described.

Service and Meter Installations

The Sutton District Water Co. lays all services, from the main up to and including the stopcock, by direct labor. It is found in practice that 70 per cent of the total number of services laid conform to certain standard lengths. Numerous stock services are therefore made up, tested and kept ready for use in the finished stores, other non-standard lengths being made up, as required, in the ordinary way. These services are now sterilized and capped off at the ends after being tested and before being put into stock or sent to the job, as the case may be. The lead pipe, ferrule and stopcock are immersed in a tank containing a dilute chlorinated soda solution for not less than 2 hr. and then drained and capped off at the ferrule and stopcock by means of standard screwed brass caps which are also sterilized. Generally a short length of lead pipe is fitted to the other end of the stopcock for the use of the consumer's plumber when making the connection to the communication pipe, in which case a cap is not required for the stopcock, the end of the short lead pipe referred to being soldered up instead. The caps, which are returnable, are not removed until the ends of the service are connected to the main or to the consumer's communication pipe. All washers and joint rings in stopcocks are

of the rubber composition type and an attempt is being made to obtain patent ferrules with joint rings of this type instead of leather.

The "ferrule-men" are provided with chlorinated soda solution and materials with which to wipe their tapping apparatus and tools before beginning to insert a ferrule in the main. All meters are also sterilized after receipt from the makers or following removal for repairs. The inlet and outlet ends are capped off with screwed caps after sterilization before being put into stock or sent on to the side for fixing. In the same way the caps are not removed until the meter is ready for connection. The sterilization of the meter is carried out by capping off the outlet end and fixing an attachment to the inlet by means of which the meter can be filled with the disinfecting liquid, in this case a weak solution of potassium permanganate.

General Measures

In common with the practice of the majority of water suppliers in Britain, this company has required that all works employees undergo a Widal blood test with a view to ascertaining whether or not they are typhoid carriers. In a large number of cases feces and urine tests have also been made. Special badges are provided to be worn by employees who have undergone such examinations.

There are no ball hydrants in the company's area of supply, all washouts and hydrants being of the screw-down or sluice valve type. The greasy or tallow packings of valve spindles are being replaced gradually with graphite packings and air valves are being displaced in favor of suitably sized air release cocks which will require manual operation. As a precaution and to maintain a good residual of chloramine in the distribution system, particularly in the service reservoirs, the residual in the effluent from the pumping stations during the period 11 P.M. to 5 A.M. is increased from the normal 0.2–0.3 p.p.m. up to 0.5–0.6 p.p.m.

All service reservoirs are roofed and manholes on the roofs or reservoirs which give access to the water are carried up well above the soil covering and are fitted, or are being fitted, with special watertight covers of the type which projects over the frame. In addition to the usual seal, these covers are provided with locking bars and padlocks. All reservoir ventilators are screened to prevent entry of vermin. The windows of valve houses are similarly screened and the window panes are of ruby-colored glass to prevent possible algal

growths in the internal sections of the reservoirs. Chlorinated soda solution, towels and special galoshes are kept inside each valve house. The galoshes are kept just inside the door and are used for slipping over the footwear of employees or visitors who may have occasion to enter the valve house, and must be used on *all* such occasions. Records are kept of all employees (other than officials of the company) who enter the valve houses or work on the exterior of the reservoirs. Should work be necessary within the reservoirs, special precautions are taken according to the circumstances of each job.

The precautions and practice briefly described in this article are designed to close possible loopholes for pollution, however slight in degree, and to help ensure that all reasonable and practical steps are taken to guard against contamination due to main- and service-laying operations, main repairs, and meter installations, during the passage of water through the various channels of the distribution system. It may be felt that some of the steps outlined are superfluous, but the question of the precautions to be taken to prevent pollution of water supplies has received such close attention from various sources recently that it is felt every precaution to this end, which is reasonable and practical, should be adopted.

Appendix

Precautions to Be Taken by Main Layers and Repairers*

"Every care must be exercised to prevent pollution when laying new mains, fixing hydrants and wash-outs or repairing or carrying out alterations to existing mains.

Sanitary Arrangements (Main Laying)

"The men must not relieve themselves in the trench, but must always use the hut and sanitary bucket provided for this purpose. Before use, the bucket is to have some disinfectant added; and, at the end of each day (or more often if necessary), the contents are to be emptied into a soil sewer manhole.

* Ministry of Health Memo. No. 221. Issued June, 1939; revised and reissued, February, 1940; revised and reissued, January, 1941.

Main Laying Procedure

"The following procedure is to be observed when laying mains:

"1. No end of any pipe in a trench must be left open and exposed, but must be sealed by means of a proper expanding pipe stopper.

"2. Before a length of pipe (or special) is lowered into the trench, the inside of the pipe must be thoroughly swabbed out with Chloros [trade name, comparable to HTH, Perchloron, etc.] solution so that the whole of the inner surface of the pipe is wetted. Immediately after cleaning in this manner the pipe is to be sealed at both ends with expanding stoppers. After the pipe has been laid in the trench and when all preparations for jointing the pipe are complete (but not before) the two stoppers from the adjacent ends of the pipes to be jointed are to be removed, and the joint made, special care being taken to see that no dirt or water enters the pipes during this latter operation. Should water be present in the trench then the water level is to be kept below the bottom of the pipes by the construction of a sump, pumping, or otherwise.

Sterilization

"No main must be brought into service until the chemist is satisfied that the main has been properly sterilized and has given his sanction for its use.

Repairs and Alterations to Mains

"When repairing mains, fixing hydrants or valves, etc., the same general procedure is to be followed as far as possible. Any water present is to be kept below the bottom of the pipes and the pipes and fittings are to be swabbed out with a mop dipped in Chloros solution. The inner surface of both the new and existing pipes, as far as can be reached, must be wetted with the solution. Following this treatment chloride of lime is to be placed in all pipes or specials which are inserted in the distribution system, before using the expanding pipe stoppers preparatory to lowering the pipes into the trench for final jointing. The amount of chloride of lime to be used in each case will depend on the size of the main and is to be in accordance with the table herewith enclosed. Chloride of lime is to be used only if the repaired main is *not* to be sterilized by means of liquid chlorine before being put back into service. If chloride of lime has been used, then, when the repair is complete, the main is to be charged slowly

from one end and left for half an hour as a pressure test. Following this a wash-out is to be opened and the main flushed until chlorine is detected at the wash-out. This wash-out is then to be shut down and the nearest hydrant or wash-out on the other side of the repaired section opened, and the main finally well flushed out through this second wash-out or hydrant. This procedure will be possible in all cases except where the damaged section of main forms a dead end of the distribution system, such as in the case of a *cul-de-sac*.

"All new mains will be sterilized by means of liquid chlorine before being put into service, and also all repaired mains of 12 in. in diameter and over.

*Amount of Chloride of Lime to Be Used for Sterilization of Various Sizes of Mains**

DIAMETER OF MAIN IN INCHES	NO. OF MEASURES OF CHLORIDE OF LIME TO BE USED†	DIAMETER OF MAIN IN INCHES	NO. OF MEASURES OF CHLORIDE OF LIME TO BE USED†
2	½	10	9
3	1	12	13
4	1½	14	18
5	2½	15	21
6	3½	16	23
7	4½	18	29
8	6	21	37
9	7	24	45

* The number of measures tabulated are calculated to give 50 p.p.m. of chlorine in 300 yd. of main.

† Amounts based on chloride of lime having 33⅓ per cent available chlorine. Measure is 2½ in. x 2½ in. x 2½ in., holding approximately ½ lb. when filled and leveled off.

"The ganger [foreman] or jointer in charge of the work will be responsible for seeing that these methods of cleaning and protecting the pipes against possible contamination are strictly adhered to, it being understood that any breach of same will be followed by instant dismissal of the person or persons concerned.

"Chloride of lime, and Chloros (or Hyclor) can be obtained from the stores. A solution of Chloros of the required strength for the swabbing process can be made by adding ½ pint of Chloros to a bucket of water."

ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31 number 3, page 481. Material enclosed in starred brackets *[ ]* is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British); I. M.—Institute of Metals (British).*

DEFENSE

Out of the Blackout. JOHN A. WEST, JR. Natl. Fire Prot. Assn. Quarterly. **34:** 4: 302 (Apr. '41). *Excerpts.*

"Greater London is an area covering approximately 700 sq.mi., but the district over which the London County Council exercises jurisdiction covers only an area of 118 sq.mi. It is within this smaller area that reside more than 4,470,000 of London's total population of 8,200,000. The London Fire Brigade protects only the 118 sq.mi. of land over which the London County Council had jurisdiction. Various 'town' brigades are held responsible for the rest.

London Fire Brigade

"In peace time, the London Fire Brigade is housed in 59 land stations and three river stations. For administrative purposes, the brigade is composed of two divisions, the first of which includes that territory north of the Thames, the second of which includes that territory south of the river.

"These divisions are further divided into three districts each, with a superintendent in charge of each district. In routine fire fighting operations, the districts are nearly independent of one another. Alarms within each of these districts are received at the nearest fire station and are transmitted to the district headquarters only. Fires requiring up to twelve pumps (equivalent to a three-alarm fire in large United States cities) are considered district calls. Should greater aid be needed, a brigade call is made to secure the help of other districts. A brigade call provides a minimum response of twenty pumps, or the equivalent of a five-alarm fire in a large United States city. District headquarters are in direct telephone contact with one another and with the central control room at the headquarters of the London Fire Brigade. Each district control station and the Brigade control room have on file the apparatus assignment cards for the entire County fire area. Local fire stations have assignment cards for their districts only.

"In peace time, the personnel of the London Fire Brigade numbers approximately 2,750 men. Equipment includes 9 turntable ladders, 8 turntable ladder pumps, 19 motor escape vans, 70 motor pumps, 63 dual purpose appliances, three emergency tenders, 21 lorries and four fireboats, and 63 miles of hose. The alarm system comprises 1,731 boxes.

"The number of actual fires attended by the London Fire Brigade in 1939 was 6,309. Deaths resulting from fires numbered 15. The property loss amounted to approximately $3,000,000.

New York Fire Department

"In comparison, the City of New York is 318 sq.mi. in area, with a population of 7,500,000, and is served entirely by one fire department. The New York

Fire Department is housed in 284 stations and nine fireboat waterfront stations which protect the 578 mi. of waterfront. The department is divided into 14 divisions, including one waterfront division, and each of the divisions is further subdivided into battalions, of which there are 48. The battalions are composed of from five to nine companies each.

"From three to four deputy chiefs are assigned to each division and are responsible to the central department headquarters. In the Boroughs of Brooklyn and Queens, the deputies are responsible to four Deputy Chiefs in Charge, who in turn are responsible to fire department headquarters.

"New York Fire Department bureaus, unlike the headquarters of the London Fire Brigade, are very much decentralized. That is, administrative headquarters, the several fire alarm central stations, maintenance workshops, training school and other branches of the department are not under one roof.

"The personnel of the New York Fire Department numbers 10,390 men working on a three-platoon basis. Equipment includes 294 pumpers, 131 hose wagons, 169 hook and ladders, 10 fireboats, 8 water towers and approximately 200 miles of hose. Within New York City there are 10,300 alarm boxes which transmit their calls to three central alarm stations; one covering the boroughs of Manhattan and the Bronx, one for Richmond, and one for the boroughs of Brooklyn and Queens. A definite plan is continually in operation for mutual assistance among these areas. All fire alarms as received are announced on the municipal radio, and second alarm calls are sent to all central stations. Provision is made for shifting companies to other boroughs as needed to cover vacated stations.

"The number of actual alarms attended in 1939 was 32,454. The number of lives lost as a result of fires was 71. Property damage during the year amounted to approximately $8,600,000.

War Conditions

"War has already brought about many changes in the organization of the British fire service, and particularly, of the London Fire Brigade.

"First, it has been found necessary to organize a centralized control more nearly the same as the peace-time control in this country. In London, all alarms are now relayed to the central headquarters of the London Fire Brigade, where the location of every fire is shown on a large map. The superintendents of the two major divisions of the Brigade are on duty at this headquarters station from which apparatus is directed about the city as needed to supplement local response.

"The increased number of fires from war incendiarism has necessitated a tremendous increase in the size of English fire brigades.

"The London Fire Brigade, for example, has been increased from its peacetime level of approximately 2,750 men, to 25,000 men and several thousands are being trained constantly to take the place of casualties. Thus far, it is estimated that nearly 3,000 London firemen have been killed or otherwise incapacitated in the line of duty.

"Fire brigades in England are being swelled from three sources: (1) ex-firemen who have enrolled as reservists and who rejoin the brigade or who make themselves available for emergency duty; (2) auxiliary firemen, including men trained to particular duties, or in the case of London, as actual fire fighters; and (3) other persons with specialized training but not with the full training of firemen.

Trailer Pumps

"Most publicized of the numerous types of equipment being used currently in England is the trailer pump. This publicity has suggested to some that these pumps might serve a useful purpose in the United States.

"Trailer pumps serve two purposes in England: (1) direct attacks on fires and (2) water relaying. Not generally known in the United States, however, is the fact that trailer pumps have always been standard pieces of equipment in the British fire service. The reason for the widespread use of trailer pumps abroad

lies in the fact that the typical English automobile engine is relatively low-powered as compared with the typical American automobile engine. European engines have been geared to low power purposely in view of the high cost of petrol. Such low power makes such engines incapable of serving the dual purpose of pumper as well as driving mechanism.

"The disadvantages of trailer pumps are many. They are incapable of carrying any large amount of hose. Space limitations also prevent the carrying of numerous small tools, ladders, poles, extinguishers and other devices which the American fireman depends upon to a considerable extent in fighting fires. Trailer pumps are also more difficult to maneuver in debris-littered streets than a self-propelled vehicle. They are too heavy, especially those units which have a capacity of at least 500 gallons per minute at 120 pounds pressure, to be handled by manpower alone.

"Conversely, trailer pumps have advantages. A trailer pumper is less expensive than a truck plus a pump. The advantages of two-piece operation of a fire company may be gained if, upon arrival at the fire, the trailer remains at the source of water and the truck continues to the fire, laying hose as it goes. Lastly, trailer pumps require a minimum of space in a fire station.

"In the 'blitz' on London of December 29 last, many water mains were either fractured or destroyed and it was necessary to relay water from London Bridge through delivery hose into the heart of the city. Trailer pumpers performed their work well. During the night, 750 pumps were in operation in London.

"Trailer pump units being used currently in England vary considerably in their capacities and pressures. Capacities range from 120 to 700 gallons per minute; pressures from 80 to 100 pounds. Such pumps in addition to being mounted as trailer units have also been mounted in small boats to augment the regular river fire floats. These small boats have proved invaluable in fighting pier and wharf fires which have occurred in the dockland area of London. In the United States, however, pumps are not recognized as suitable for supplying fire streams unless they can deliver at least 500 gallons per minute at 120 pounds pressure.

Government Control

"Fire has now threatened Britain as a whole and has become a national problem. The Home Office has assumed some degree of authority over fire fighting forces, but not with entirely favorable results, for, naturally, the national government is inexperienced in the matter of fire service technique and in the matter of fire brigade administration. Specifically, some of the numerous objections to Home Office supervision of the fire service have been as follows, according to reports.

"*First:* It was the Home Office that selected and placed fire-watchers, but in so doing, felt it necessary to place them on large premises only. Smaller buildings were disregarded. Naturally, large buildings of iron and concrete construction are capable of withstanding the shock of explosion and flames and heat more thoroughly than the small, antiquated buildings which have suffered the greatest damage in the 'blitz.'

"*Second:* The national government has suggested that the Home Guard take among its duties the fighting of war incendiarism. This has stirred resentment among the officers and men of the fire service, who feel that the fire problem is one in which men with specialized training are more valuable than large numbers without adequate training. It is felt among the men of the fire service that the Home Guard is a military unit and not one qualified to augment fire fighting forces.

"*Third:* The Home Office has also interfered with the fire service by approving a 'test' incendiary bomb which the fire service recognizes as nothing more than a flare. The fire service approves another 'test' bomb. Incidents of this type seem petty, of course, but create friction which is not healtuful and which cannot be tolerated if victory is going to be an ultimate achievement.

"*Fourth:* The fire service expects the national government to feed and generally care for fire fighters on duty outside of their own areas, for, naturally, in 'blitzed' towns, there is a scarcity of food, and gas, electricity and water services are usually interrupted. The national government, on the other hand, believes it is the problem of the 'blitzed' town to feed reinforcements. Suggestions have been made that mobile canteens be equipped and used to serve 'blitzed' areas and, particularly, the reinforcing fire fighters in such areas.

"*Fifth:* There is growing discontent over the fact that fire brigades are not always under the command of qualified officers of the fire service.

Sprinkler Systems

"Sprinkler protection . . . has already proved its worth against the incendiary bomb and against the fires resulting from both explosive and incendiary bombs.

"The incendiary bomb is incapable of completely destroying either a sprinkler system or its water supply. After a bomb has penetrated the roof and the ceiling below the roof, little momentum remains for it to do further damage. And, of course, the typical incendiary bomb does not explode.

"Upon impact, the thermite within the bomb reacts and its shell of magnesium is set ablaze. The type of water distribution produced by a sprinkler head is suitable for combating the incendiary bomb, and for all practical purposes the spread of fire to any surrounding material may be said to be similar to a peace-time accidental fire. The water from sprinklers will probably not extinguish the bomb, but will keep the surroundings cool and hold the fire in check.

"Naturally, a sprinkler system cannot withstand the shock of an explosion which cannot be withstood by the building in which the system is installed. Generally, however, a sprinkler system can withstand a shock that the building can withstand. Thus, if a building is partially destroyed by an explosive bomb, the sprinkler system in that section of the building can be expected to be destroyed also."

[Part II of this article is an account by a professional fire officer of his personal experiences during one night of "blitz." See following abstract for review of article as it appeared in another publication.]

Fighting Blitz-Fires in London. ANON. Fire Eng. **94:** 173 (Apr. '41). Personal impressions of London professional fire officer in charge of sector of London, obtained during emergency duty fighting London's great dockland fire on night of Sept. 7–8. Glare from fires 12 mi. distant rendered unnecessary car lights for driving, heated air from fire poured into car when fire still 5 mi. away. Great difficulties encountered in reaching fires because of destroyed roads, presence of unexploded bombs and debris from shattered buildings. Author assigned section of fire in tar distillery, timber yard and warehouses with oil depot nearby. Description given of fighting of fire during incessant, systematic bombing by enemy. Broken water mains necessitated use of any stream water available. Describes incident wherein water from small stream flowing by oil depot became diluted with oil, creating greater temporary fire hazard when pumped onto flames. Lessons learned from emergency included worth of having own personal subordinate present; importance of uniform pre-arranged methods of fire fighting; having skilled mechanic and tools along; and desirability of carrying supply of drinking water for men. Heroism and bravery of London firefighters praised.—*Martin E. Flentje.*

Air Raids and the Sanitation Problem. A. MASSEY. J. Roy. San. Inst. (Br.) **41:** 141 (Apr. '41). *Excerpts.*

"The sanitation problem is created primarily by (a) fractured or smashed sewers allowing the outflow or backing up of sewage into bomb-craters, streets, basements, cellars, etc., and (b) damaged water pipes cutting off water supplies and causing a suspension of the water carriage system for sewage disposal in the affected areas. It is noteworthy that the lack of normal water supply, despite the many inconveniences and public health disadvantages it occasions, does

at least limit the problem of escaping sewage.

"In a town which has suffered widespread air raid damage to sewers and water mains, a policy must at once be determined in regard to temporary arrangements for sewage disposal pending the restoration of normal services.

"Should the public be advised to resort to a conservancy system—using pails and burying the excrement? If so, the local council would also need to provide latrines—on the army system—at convenient points in open spaces, public parks and the like. The average sanitarian would wish to avoid the introduction of these primitive expedients in urban areas. The wartime civil labour shortage is also a contra-indication in the matter of latrines, provision having regard to the difficulty of regular emptying and cleansing.

"The alternative is to keep the water carriage system working, under improvised conditions and subject to certain measures of control. It was essayed to do this in Coventry in circumstances of unprecedented difficulty following the big raid of November 14-15, 1940.

"Commencing immediately after the raid, engineering workers and sanitary inspectors collaborated in making rapid surveys of the city to locate and assess the damage to sewers and drains. Day by day the cases of damage, thus ascertained and classified, were reported in order of urgency to the sewers section of the City Engineer's Department and numerous gangs were employed in performing prompt first-aid work. At each site of damage, first-aid consisted in clearing the communications by rodding the distal sections and making temporary open clay channels on the 'split pipe' principal to permit the flow from proximal to distal sections of the broken sewers. In many cases, of course, the sewage had to be pumped out of craters, basements and cellars. It was pumped into tumbler [dump] carts and was then taken for disposal to the nearest manhole serving an intact sewer. The craters, basements and cellars were duly disinfected and deodorised. The permanent making good of broken drains and sewers followed on with all possible speed.

"Although the occurrences of damage to water pipes and sewers were very numerous, the instances of damage to both in a common crater happily were few. In the latter cases, the affected sections of the water system were effectively isolated from the main circuit pending the repair of mains which was quickly in hand.

"There remains to be mentioned the means employed to secure emergency water flushing facilities for the closets remaining in use in those damaged areas which were temporarily deprived of the ordinary town's water supply. In the latter connection, central courts and common yards presented a particular difficulty and numbers of water closets of the communal type were at first without water for flushing. Surface water mains were quickly brought into use and standpipes were provided at appropriate points. Pending this provision water carts patrolled the affected areas. By these means, the inhabitants were able to obtain water for various domestic purposes including the hand-flushing of closets. The local practice of providing rain-water storage tanks in connection with many types of house property proved of value in many ways during the difficult days following the big raid; not least of these was the use of a part of these pre-existing reserve water supplies for closet flushing. This reserve provision of rain-water, however, was not usual in courts and common yards; hence the special initial problem constituted by this class of property as mentioned above.

"It is suggested that, wherever possible, a policy of maintaining some kind of water carriage system is preferable in an urban area to any hasty reversion to conservancy methods."

Billeting in Liverpool. GEORGE BINNS. J. Roy. San. Inst. (Br.) **41:** 143 (Apr. '41). *Excerpts.*

"The Civil Defence Emergency Committee arranged for the establishment of an efficient billeting organization at the outbreak of the war, when the chief sanitary inspector was appointed as chief billeting officer. Since that time all civilian billeting in the city has been

co-ordinated by him, whose staff of sanitary inspectors have acted as billeting officers.

"The first duties falling on the Billeting Department were the provision of billets for certain A.R.P. [air raid precautions] and hospital personnel and the supply of lists of accommodation to certain Government departments requiring billets in the city. To avoid overlapping, all civilian organizations requiring billeting accommodation work in co-operation with the chief billeting officer, who also keeps in contact with the police and military authorities in regard to the billeting of service personnel.

"The Civil Defence Emergency Committee, with a view to making every possible advance preparation, authorised the chief billeting officer to undertake a complete survey of all available accommodation in Liverpool. This survey, which required the services of the entire billeting staff for several weeks, was carried out before the air raids on the city commenced, and it is believed that Liverpool is the only local authority which undertook such a survey at that time.

"Persons rendered homeless during air raids are provided with temporary shelter in emergency rest centres, and it is the duty of the Billeting Department to find the billeting accommodation for these people. On the morning following air raids, billeting officers attend at the rest centres to assist all people requiring accommodation and, in addition, billeting officers visit the damaged houses to make contact with people who may be in need of accommodation but who have not attended the rest centres. Families whose homes have been made permanently uninhabitable are, in addition to being offered immediate billeting accommodation, provided with a certificate by the billeting officer to the effect that the family needs rehousing. On production of this certificate at the Housing Department, all possible steps are taken to rehouse the family in permanent accommodation. The provision of permanent accommodation is, of course, a difficult matter, but it is being assisted to some extent by the requisitioning of privately-owned unoccupied houses which are selected by the chief billeting officer. These houses after being requisitioned by the local authority, are let to families at rents they can afford to pay. Families temporarily homeless owing to delayed-action bombs or the need for first-aid repairs to their homes, usually require billeting accommodation for only a comparatively short period.

"The billeting of homeless persons on private householders is on a 'lodging' basis only, and the householder is merely required to provide accommodation with reasonable access to water and sanitary facilities. Householders are not required to provide food, and they are paid five shillings per week for each adult and three shillings per week for each child under fourteen years who is billeted in the house. This money is recoverable by the householder from the post office. It is, of course, found in practice that most householders do not adhere strictly to the terms of the billeting notice, but do all they can to assist the people who are billeted with them and to make them comfortable in their new accommodation. Many people manage to make their own private arrangements for billets with relations or friends, and in such cases the same billeting allowances are payable. Until recently, billeting allowances were not, however, payable if homeless persons found billeting accommodation outside their own town, but this has now been altered by new instructions from the Government.

"Although billeting has been carried out in Liverpool on a considerable scale, it has so far proceeded quickly and with almost no complaint. It is a difficult problem for all concerned; the homeless person is inevitably in a distressed condition and in need of every consideration, whilst the householders who receive the billetees are themselves making a revolutionary change in their lives in surrendering part of their homes to strangers. The responsibility for seeing that billeting runs smoothly rests with the chief billeting officer and his staff, but they are powerless without the co-operation of all parties affected. It has been the experience of the Billeting Department in Liverpool that homeless persons ac-

cept their difficulties with an amazing fortitude and cheerfulness, whilst most householders do all that they can to make their new guests comfortable. It is vital to the spirit of the community that this co-operation by householders should continue."

Material Available for Water Supplies. C. BIEMOND. Water. (Neth.) **25:** 1 (Jan. 10, '41). Report. of com. on material available for rebuilding of destroyed water works and for necessary expansion shows that asbestos, non-ferrous metals, iron and steel, lubricating oil, textiles and rubber of greatest importance. Asbestos-cement pipe can be produced in limited quantities; sufficient for rebuilding but greatly restricted for new works. 6 mo. requirement of block-lead is 200 tons, lead pipe, 300 tons, copper pipe, 50 tons and tin solder, 5 tons; sufficient available for few months. Permission given to use existing supplies for repairs. Need for 6,000 tons cast-iron pipe and 1,000 tons steel pipe; supply sufficient for 5 mo. (until Mar. '41). About 70% of lubricating oil has been allowed; bitumen available only for anti-corrosion. Jute and textile products which must be imported sufficient till Jan. '41; needed 40,000 kg. for next 6 mo. With great difficulty, 4,000 kg. jute allowed. Rubber requests for water supply has preference. Chemicals and building materials subject to negotiations. Com. tries to be fair, but subject is difficult. Many complaints. No individual system or community can buy. Reworking of old material prohibited. Must be delivered to central point, while only ⅔ returned.—*Willem Rudolfs.*

Fences and Guards Protect Water Supply. ANON. Am. City. **56:** 3: 42 (Mar. '41). Defense measures to protect supply of New Haven, Conn., from sabotage have been completed by water co. System ideally situated for such defense, 16 reservoirs being scattered over more than 25 sq.mi. Both high and city pressure systems supplied from interchangeable sources. Fences built around reservoirs, dams and pipe lines. 17 deputized employees act as guards at important structures where visiting has been curtailed. 3 valves at all street intersections permit uninterrupted service when main damaged. Additional tie-in with neighboring power system being completed. With only 1 reservoir capable of supplying needs of area for year, officials believe New Haven better prepared for emergency than any city in country.—*F. C. Maier.*

Geared for Boom Town Growth. EDWARD J. CLEARY. Eng. News-Rec. **126:** 325 (Feb. 27, '41). Fayetteville, N. C., 9 mi. from Fort Bragg, where 12,000 construction men are building accomodations for 66,000 troops, is well organized to take care of the expansion which will undoubtedly follow establishment of camp. In '06, water, sewer and elec. services were placed under direction of non-partisan public commission, and present mgr. has held office for 21 yr. Pop. is 18,000, but metropolitan area, which includes some 30,000 people, is served. Water consumption is 2 m.g.d. and capac. of filter plant 3 m.g.d. Latter will be increased to 5 m.g.d. in near future. Construction of 1-mil.gal. elevated tank will be undertaken soon and also installation of 300-h.p. diesel engine for standby pumping. New mains in housing subdivisions are constructed by subdivider in accordance with plans and specifications of Public Works Commission and latter reserves right to purchase mains at any time. Price is determined and contract stating agreed price is signed on completion of work. These pipelines are purchased only when they are incorporated in grid system and inter-connected to ensure better distribution and pressure. This has proved to be economical procedure.—*R. E. Thompson.*

Utility Regulation and National Defense. *Report of Com. on Progress in Public Util. Regulation.* National Assn. of R.R. & Util. Comrs. Washington, D. C. (2nd ed. Feb. '41). Report recommends stricter regulation, federal and state, and more opportunities for public ownership. Space given to analysis of European military history and recent war events, with view to showing relationship between utility operation and national defense.—*Samuel A. Evans.*

WATER SUPPLY GENERAL

Hotel Engineering. *Vol. 1. Water Consumption, Cost and Savings.* GEORGES C. ST. LAURENT. Booklet of Am. Hotel Assn. ('40). Cost of water to hotels becoming generally higher due to increasing water use for air-conditioning, without reclaiming cooling water, general increases in water rates, and sewage disposal payments in some communities in direct ratio to water consumption. Study tabulates in considerable detail 202 complete answers to 2 questionnaires of 726 received from hotels located in all sections of country. Major sources of water consumption in hotel are guest rooms and public lavatories, kitchen and pantries, laundry, air-conditioning and refrigerating equipment, boiler room and eng. dept. Report urges sub-metering of these and other important sources of consumption. Pointed out small faucet leak $\frac{1}{32}$" in size can result in loss of 52,000 gal. per yr., $\frac{1}{16}$" over 200,000 gal. per yr., and that leaky lavatory fixture will ordinarily waste as much as 200,000 gal. in same period. Flushometers and toilet tanks should be adjusted to give uniform flow, and public lavatories provided with hand- or foot-operated flushing devices instead of continuous flushing arrangements. Ave. temp. of hot water in hotels reported to be about 160° F., varying from 130° F. to 180° F.; should never exceed 135° F.; human body cannot stand hot water temp. much over 120° F. Heating to high temps. may raise water cost as much as 25% and, with aggressive water, will reduce life of some pipe materials as much as 30%. In kitchen, faucets should be checked for leakage at least once weekly and heavy duty faucets used. Water used in vegetable washing can be recirculated and re-used after straining. Both inlet and discharge water valves of laundry wash wheels should be maintained in first-class condition to prevent waste of water. Air-conditioning equipment requires large quantities of water for condenser cooling purposes, using anywhere from 1 to 3 g.p.m. per ton. For example, 25-ton air-conditioning installation will consume about 85,000 gal. water in 24 hr. Number of ways available in which cooling water can be re-used; evaporative condensers costing $50–$75 per ton of air-conditioning will save 90% of cooling water for re-use purposes—generally not used when installation over 100-ton capac. Another method is through use of cooling tower. Wastage of water easily possible in boiler room and frequent inspection and repair of all valves recommended. Ave. size of hotels reported is 354 rooms—min. 47 and max. 2,710. Following series of figures refer to ave., min. and max. values respectively of all 202 hotels: room rate $3.37 (ave.), $9.95 (min.), $11.00 (max.); per cent occupancy: 59%, 29%, 96%; ratio of food and beverage sales to room sales; 104%, 14%, 322%; water consumption per occupied room per day (gal.): 400, 66, 1,144; water cost per available room per day: $0.0299, $0.0051, $0.0806; water cost per occupied room per day: $0.0506 $0.0078, $0.1925. Total quantity of water used by these 202 hotels in '39 amounted to 6,173 mil.gal., ave. of 30 mil.gal. per hotel; total cost was $781,084, ave. per hotel, $3,866. Hotels subdivided into 14 groups in accordance with facilities. Data for each group tabulated in considerable detail. Groups having lowest water consumption were Group 1 numbering 9 hotels operating low pressure boilers, no kitchen, laundry or air-conditioning; Group 2, 26 hotels, facilities same as Group 1, except having kitchen; Group 10 with 6 hotels which buy high and low pressure steam, operate kitchen, no air-conditioning. In these 3 groups the: (1) ave. water consumption per day per available room and per occupied room in gal.; (2) ave. water cost per day per available and per occupied room; and (3) water cost per dollar room sale, were respectively: Group 1—(1) 115, 161; (2) $.0134, $.0188; (3) $.0138. Group 2—(1) 109, 162; (2) $.0181, $.0270; (3) $.0117. Group 10—(1) 101, 144; (2) $.0232,

$.0333; (3) $.0159. The 3 groups having highest water consumption facilities were: Group 9, 36 hotels operating high pressure boilers, kitchen, laundry, some air-conditioning; Group 12, 11 hotels, buy high and low pressure steam, operate kitchen, laundry and some air-conditioning; Group 14, 19 hotels, make steam and electricity, operate kitchen, laundry and some air-conditioning. For these hotels, the above figures in the same order are: Group 9—(1) 272, 480; (2) $0.0320, $0.0562; (3) $0.137. Group 12—(1) 308, 533; (2) $0.0365, $0.0632; (3) $0.0187. Group 14—(1) 297, 511; (2) $0.0401, $0.0689; (3) $0.0164. Illustration given how one hotel reduced water consumption 43% through installation of cooling tower and inauguration of water economy program.—*Martin E. Flentje.*

Engineering Practice in Relation to Water Supply Activities. W. A. ROBERTSON. State Rivers & W. Supply Com. (Victoria, Australia) ('39). Describes investigations made by author by direction of Govt. of Victoria, into eng. practice in relation to water supply in U.S., Great Britain, France, Switzerland, and Italy. First part of report deals with irrigation practice in western states of U.S., where conditions are very similar to those in Victoria. Work of Bureau of Reclamation, and no. of irrigation projects in Wash., Calif. and Ariz. described. Where surface supplies are scarce, or already overtaxed, some districts withdraw water from underground layers and re-use it for irrigation. This has additional advantage of controlling level of water table, which may be raised by irrigation to such extent that roots of crops may be killed by water-logging or by toxic concentration of soil salts. Repeated use of percolated water, however, results in increasing salinity of water. Chem. analyses of water for irrigation now carried out in America are described and accepted standards of quality given. Dissolved salts in soil solution exert important effects both on physical state of soil and on plant growth. High percentage of sodium reduces permeability of soil. Exchange reactions apparently do not take place between anions as they do between cations and constituents of soil. High content of chloride is generally considered to be more toxic to plants than high content of sulfate or carbonate. Permissible content of dissolved solids in irrigation water varies in different districts. Development of irrigation by ground water supplies avoids cost of additional reservoirs for storage of surface water, but requires installation and maintenance of pumping plant; drainage of soil improved by this measure. Comprehensive investigations from geological, hydrological, chem., and economic standpoints required before deciding on practicability of this method for Victoria. Second part of report describes inspections of design and construction of about 40 reservoirs in various countries. In each case, geology and hydrology of district, capacity of storage, design of dam, and details of construction given. Those developments which appear to have possibilities for adoption in Victoria emphasized.—*W. P. R.*

Design and Construction of Outdoor Swimming Pools. E. H. DARLING. Can Engr. **78**: 7: 7 (July '40). Detailed discussion of foundations, protection against frost, provision for drainage, contraction and expansion, reduction of concrete shrinkage to min., etc. Requirements for satisfactory construction are met by 2,500-lb. concrete of nominal proportions of 1:2:3.25 mix. Workable mix that can be properly vibrated requires but 5½ gal. water per sack of cement, giving slump of 4-5″. Except in special cases, no economy in making walls less than 8″ thick and floor slab should not be less than 4″. Unit stresses recommended are 12,000 lb. per sq.in. for steel and 650 lb. for concrete. Area of reinforcing steel required is about 0.03% of area of concrete section. Expansion joints are usually placed at 75′ intervals. They are expensive and sometimes require considerable maintenance and, therefore, no. employed should be reduced to min. Sheet copper, folded to allow movement and extending length of joint in one piece, is favored by author. Smooth finish adds to attractiveness of pool. Painting should be avoided owing to expense involved and constant maintenance required. Scum gutters add to

expense of pool construction and are retained largely from habit. Shallow trough along side of pool walk would serve as gutter also. Usual spoon-shaped bottom is satisfactory for small pools. For pools 100′ or more in length, 2 separate pools, one for divers and one for swimmers and beginners, is more advantageous. Water at shallow end of pool is dirtiest owing to greater use and to present practice of introducing water around top of pool and drawing it off bottom at deep end draws this dirty water full length of pool. Adding clear water at deep end and drawing off dirty water through series of outlets along wall at shallow end would avoid this.—*R. E. Thompson.*

Municipal Works and Worries. Edward J. Cleary. Eng. News-Rec. **126:** 224 (Feb. 13, '41). Review of outstanding developments during '40. With flow of federal funds stopped and psychology of nation shifted from domestic pursuits to national defense, marked deceleration in construction of sanitation works occurred. Expenditure for sewage disposal and water supply construction in '40 was only about ½ all-time high of '39. Stream pollution control progressing. Splendid headway made during last decade in installation of munic. treatment works but speed-up on national defense work will probably defer demands for waste treatment on industry. Important developments in water supply were announcement that federal code of water works being formulated and Supreme Court decision in New R. case. In latter, Court ruled that if stream (no matter how small) can be improved by dredging or construction of dams so that it will float barge, or even logs, may be classed as "navigable" and thus under federal and not state control. Other developments included introduction of "break-point" chlorination and revived interest in ozonization. All-welded steel pedestal type water tank suddenly became popular, 10 installations following first such structure in Longmont, Colo.; and radial ground water collector, novelty when first described, making bid for popularity.—*R. E. Thompson.*

City Planning and the City Water Problem. W. J. Powell. Tex. W. W. Short School. **22:** 71 ('40). Failure of legislature of Tex. to continue Texas Planning Board regretted because greater economy and better water systems evolve when cities have 5- to 6-year program, properly co-ordinated with larger long-range plan of watershed in which cities lie.—*O. M. Smith.*

Water Plant Operation During a Tornado. John E. Robertson. Drippings From Georgia Faucet. (Mar.-Apr. '40). 3 pp. Water service to Gainesville, Fla., continued after tornado destroyed part of town, and elevated storage tank was emptied of water through broken connections and fire fighting. Water plant was not damaged because of remote location. High service pump was operated continuously under pinched-down discharge to give discharge equal to max. rate of filtration, about 900 g.p.m. Author makes following recommendations to prepare for similar condition: (1) Provide stand-by power source. (2) Have duplicate copies of map records of pipes and valves of distr. system filed in different bldgs. (3) Have quick means of identifying city officials so they have no trouble in gaining access to city bldgs. and property if martial law is declared. (4) Public Health officials are cautioned to know men and plants under their jurisdiction. (5) Water works men are cautioned to know san. engr. or public health official.—*P.H.E.A.*

Water Service Practice. A. C. Warren. Ill. Munic. Rev. **19:** 220 (Nov. '40). Elmhurst, Ill., pop. 15,000, served with water from 4 wells, one of which used in emergency only. Fifth well being drilled. Approx. 4,100 homes and bldgs. served. City fully metered. Meters furnished by consumers, but maintained by city, except as to breakage from abuse or neglect. In '36, water dept. combined with sewerage dept. for purpose of financing sewage treatment. As aftermath of political heckling, considerable resistance encountered to revenue charge for sewage disposal, both when proposed and when put into effect. Interesting

from psychological view that no. of originally bitter opponents now enthusiasts, although direct benefit to them is no greater than promised. Tests for home leaks made upon request or upon suspicion. Meter-readers carry aquaphones and, at intervals, or upon any inaccountable increase in monthly quantity of water used, test by sound made, with all house fixtures closed. Breaks of 50 to 100 g.p.m., or unusual accumulation of small leaks can be indicated on pumping station charts between hours of 1 and 5 A.M. Chem. analysis of any deep well open to several water-bearing strata may vary according to: (1) rate of pumping at time sample was taken; (2) length of time elapsed since previous pumping; and (3) same factors as applied to any neighboring wells. For obtaining small samples of water for chloride analysis from various depths during pumping operations, short suspended tube having chambers separated by lead seal used. Upper chamber filled with mercury, which in given time destroys seal and flows into lower chamber, so that water desired drawn into upper chamber. Tube ½″ in diam. and will pass usual pump setting. Determination of chlorides proved useful in studying circulation of water through mains, and in identifying cut when in doubt as to source of water which might be evidence of leak.—*H. E. Babbitt.*

Two Hundred Years of Waterworks Development in Bethlehem, Pa. R. D. Billinger and R. W. Woodring. Am. Chem. Soc.—News Ed. **18:** 1132 (Dec. 25, '40). Bethlehem, Pa. water works dates from 1754 and frequently cited as first successful water works in U. S., though Boston has been credited with public water supply in 1652 and Shaefferstown, Pa., in 1732. Original Bethlehem works used water power from Monocacy Creek to force spring water 70′ (later 112′) to wooden cistern. Original pump and pipes were of wood. Later lead pipes were made of sheet metal, soldered and laid in pitch and brick dust. 3 cast-iron pumps installed in 1761 and replaced in 1832 by large double-acting pumps. In 1786 water led from central distributing tower to 7 other cisterns or water boxes. Cast-iron pipes introduced in 1813. Old spring served as water source until 1912 when artesian wells 700′ and 750′ deep were developed, later supplemented by 1,013′ well yielding 2 m.g.d. In 1875 pumping system installed to bring water from Lehigh R. In 1886, 2 reservoirs with joint capac. of 3 mil.gal. built. In 1892 new 12 mil.gal. res. added 250′ above river. Slow sand filters introduced in 1904 and 6 rapid sand filters added in 1917. Sponges used first in preliminary filters, later supplanted by coarse coke. Anthracite coal (Anthrafilt) used successfully last 6 yr. in addn. to sand, and chlorine for over 20 yr. Coagulants also employed. At present, chloramine treatment replaces simple chlorination. Pumps force river water at 105 lb. static head to sedimentation basins, and, after treatment, some of it is pumped still higher at 125 lb. static head to res. serving hilly section. About 86% of present supply obtained from Lehigh R. During drought and heavy contamination, bact. problem requires drastic chem. control which sometimes causes complaints. Water quite hard. Under recently formed Bethlehem Municipal Water Authority, first such organization in Pa., new supply project being carried out with P.W.A. grant to bring pure stream water from Wild Creek, 30 mi. away. Should be completed early in 1941. Earth-fill dam of 1,160′ being built to impound water from 22 sq.mi. of Wild Creek watershed. Res. will have 300-acre area and normal capac. of 4,500 mil.gal. Specially designed spillway, channel and stilling basin devised from large model constructed by A. T. Ippen in hydraulic lab. of Lehigh Univ. Univ. has at frequent intervals and sometimes for long periods furnished advice and consultants in bact., chem. and eng. problems of water control. Water from Wild Creek will flow by gravity from 820′ elev. at dam to 340′ at Bethlehem, through 22 mi. of pipe line and 2.5 mi. of tunnels. Line will vary from 36″. diam. at source at 20″ at terminus. Total cost approx. $4,000,000. Total hardness of new supply is 7.9 p.p.m. compared with 136 and 237 p.p.m. in sources now used.—*Selma Gottlieb.*

Softening and Filtration in Compact Plant. ANON. Am. City. **56:** 2: 52 (Feb. '41). Water works at Parkersburg W. Va. obtains water from 16 Layne gravel-wall wells along and adjacent to Ohio R. Pump houses mounted on top of well casings, 3½′ above max. high water. After aeration and settling, water divided equally between zeolite softening units and rapid sand filters. Softeners reduce hardness to zero from max. of 167 p.p.m., leaving mixed water with hardness of 70 to 80 p.p.m. Filters remove much of precipitated iron. Lime added for pH control and chlorine to produce residual of 0.2 p.p.m. in clear well. Two electric-driven centrifugal pumps supplemented by older steam-driven equipment provide high lift service.—*F. J. Maier.*

Quality—Not Quantity—Sought for New Water Supply. LEO W. ALLMAN. Am. City. **56:** 5: 64 (May '41). Abandoning nearby source of plentiful but unsatisfactory water from 54 wells, Wichita, Kan., has gone 33 mi. away to new well field. New supply reduces hardness from 370 to 130 p.p.m., chlorides from 490 to 25 p.p.m. and improved taste. Built with aid of P.W.A., project involved 27,000 tons of pipe. Water rates increased 15%.—*F. J. Maier.*

Small-Town Water Works. E. F. HOOVER. Am. City. **55:** 9: 81 (Sept. '40). Centerburg, Ohio, pop. of 775 (270 active services), no doubt one of smallest towns with water works. In '36, iron-removal and softening plant built. One-story brick building, 120′ x 42′, houses treating equipment for water from one well, 70′ deep, now in use. Raw water first enters mixing tank where lime added; then goes to settling basin. Carbon dioxide added following settling and before filtration and storage in an elevated tank. Raw water has hardness of 272 p.p.m., iron content of 1.2 p.p.m. and 2.0 p.p.m. of fluoride. Treatment reduces this to satisfactory hardness of 70 p.p.m., iron content of 0.1 p.p.m. and fluoride of 1.0 p.p.m.—*Arthur P. Miller.*

Water for a Desert Town. HERBERT T. BRUCE. Eng. News-Rec. **125:** 703 (Nov. 21, '40). Brief description of water supply of Elko, Nev., written in popular style. Elko, pop. about 4,000, fifth largest city in state. Water supply franchise purchased from private owner in '23 and, since then, supply progressively increased to 0.82 m.g.d. No reliable surface supply. Good water obtained only by drilling through strata of clay and rock to depth of 70–100′. Water pumped from 4 installations, located in different parts of city, to 2 storage tanks situated on hill and holding ½-day supply. Deep-well pumps driven by diesel engines. Auxiliary gasoline motors used to start diesel engines also serve as standby units. Bond issue of $330,000 now nearly amortized. City levies no general water tax, yet water works is self-supporting. Only stores, garages and similar commercial bldgs. charged for service. Min. water rate 30¢ for first 1,000 gal. and 10¢ for each additional 1,000. Swimming pools also operated by water dept.—*R. E. Thompson.*

Tucson's Water Works Improvements. J. A. CAROLLO AND P. J. MARTIN, JR. W.W. & Sew. **87:** 505 (Nov. '40). Tucson, Ariz. planned general program of improvements. Extreme corrosiveness required choice of special valve materials and corrosion-proof pipe. Jointing experiences and bid prices for major contracts given. Improvements include installation of 2 elevated storage tanks and ground level reservoir. Resultant savings in operation should pay entire $500,000 cost within 10 yr.—*H. E. Hudson, Jr.*

Small Surface Water Supply in New England. ANON. Am. City. **56:** 1: 56 (Jan. '41). Great Pond source of raw water for 2 filtration plants, 1 serving Randolph and Holbrook, Mass.; other Braintree, Mass. Randolph plant, completed in '36, consists of 2 low-lift pumps discharging into mixing tank adjacent to 4 dry feeders applying soda ash, alum and activated carbon for color and odor removal. Following coagulation, filtration and chlorination, finished water pumped to distr. system with steam-driven, cross-compound high-lift service pump. With standby steam pumping equipment, only inconvenience experi-

enced during electric power failures has been necessity for operating electric-driven dry feed machines manually.—*F. J. Maier.*

Behind the Scenes at Concord, N. H. NATHAN N. WOLPERT. W. W. Eng. **93:** 1284 (Oct. 9, '40). Concord, N. H., located 125 mi. from Canadian border. Water supply obtained by gravity from 365-acre Penacook Lake and pumped well supply 3 mi. from city, consisting of 150 wells, 38′ deep, supplying 1.5 m.g.d. Copper used for services up to 2″ in size, cast iron, cement lined or plain, used for larger ones. "Leadite" used for pipe joints with small pellet of lead inserted in joint to complete electrical circuit if necessary to thaw out main when frozen. Mains across bridges placed in 3′ wooden box filled with granulated cork for prevention of freezing. In past yr. only 12 services frozen. Hydrants regularly inspected in spring and fall; weekly, however, during winter. Hydrants on low service painted orange, on high service orange with aluminum tops and caps, on extra high service with aluminum top and caps. No standard spacing of valves in distr. system carried out. Meters owned by dept. and set on consumer's premises free, placed in cellar. Large meters read monthly, domestic meters read every 6 wk.; all billed quarterly. In locations on system where freezing apt to occur due to poor circulation, water wasted at selected houses by installing faucet washer with narrow groove cut across face preventing faucet from seating properly and allowing small leak to flow continuously. Free water supplied 7 wading pools amts. to approx. 175,000 g.p.d.—*Martin E. Flentje.*

The Story of P.W.A. in Maine Water Works. F. J. RENY. J.N.E.W.W.A. **54:** 282 (Sept. '40). Resumé of some water works projects constructed with P.W.A. grants. Portland (Me.) Water Dist. completed 3 projects with total cost of $830,008, receiving aid in form of grants of $369,279. Total cost of projects in Me. aided by P.W.A. equalled $2,011,300; all received grants of 45% of cost. Engrs. believe 25 to 30% of grant salvaged.—*Martin E. Flentje.*

Annual Report, Year Ending Sept. 30, 1939. *Water Works Com., Quincy, Ill.* Report in tabular form. Plant investment to Oct. 1, '39 (after depn.) equaled $1,830,944; total income for yr., $309,623; total expense, $120,634. Of 9,891 total services, 8,699 are metered, 1,158 on flat rate and 34 on fire protection service. Ave. daily consumption 2.919 mil.gal., equaling daily per capita consumption of 72 gal. During yr. 1.08 mi. of new main laid, largely 6″, bringing total mileage in system to 111.05 mi., 77.11% of which is 6″, 7.26%, 8″; 3.75%, 10″; and 3.77%, 12″. 33 valves set in '38–'39; total in system, 1,186. 669 fire hydrants in service. Ave. 37°C. bact. count of river water before treatment (for yr.) was 1,129; softened water, 81; final effluent, 2.7; distributed, 3.2. Coliform presumptive tests positive 99% in 1.0 ml., 81.6% in 0.1 ml. and 22% in 0.01 ml. tests of raw water; in final eff. 0.41% of total 10 ml. tubes positive on completed test, 0% on distr. system samples. Ave. chem. dosages in lb. per mil. gal.: alum, 567; lime (CaO), 1,189; carbon, 67; ammonium sulfate, 13; and chlorine, 11.12. Ave. turbidity filtered water, 0.03 p.p.m.; color, 3, total alky., 52 (phenol, 13); total hardness, 114 (raw, 180); ph, 9.0.—*Martin E. Flentje.*

4th Annual Report, Little Rock, Ark., Municipal Water Works. *Year ending Dec. 31, 1939.* Report covers first full yr. of normal operation with present supply under munic. ownership. Plant, property and equipment now valued at $6,817,375; total govt. grants received $934,627. Total operating revenue for yr., $632,812, an increase of $20,912 over previous yr.; operating expenses increased $3,349 to $174,814. Impounding res., Lake Winona, filled on Jan. 10 and remained full until end of June, then fell to new low of 6.2′ below spillway elev. Flow tests during yr. revealed decrease in carrying capacity of transmission main from 25.32 m.g.d. to 20.38 m.g.d.; due to organic growths on pipe walls, largely corrected in 6 mo. of $ClNH_3$ treatment. Treatment problems encountered during yr. included sloughing off of old incrustation in mains, causing discolored water, and corrosion in hot water plumbing—both problems remain-

ing unsolved at end of yr. Mean rainfall for yr., 50.37″, 2.67″ over normal. Pop. supplied, 90,945 in Little Rock and 20,745 in North Little Rock—111,690 total. Per capita production, 63 gal. per capita; per capita use, 51 g.p.d. Ave. daily consumption, 5.74 m.g.d.—1.12 m.g.d. going to North Little Rock. Total metered consumers equalled 18,251, of which 83.38% were domestic and 14.93% commercial. In addition, 98 fire services on system bringing total of consumers to 18,349. Ave. monthly bill: domestic, $1.73; all classes, $2.71. Total cost of all chemical used at purification plant, $8,426; $3.28 per mil.gal. Made up (partly) of $1.42 for alum, $0.59 for lime, $0.52 for chlorine and $0.14 for carbon. Turbidity of raw water: 4 (ave.), 25 (max.) and 2 (min.); hardness of effluent: 27, 44 and 16; alkalinity effluent: 25, 44 and 16; pH of effluent: 9.0, 9.5 and 7.6. Ave. count raw water: 11, effluent: 1. Coliform index: raw, 7.8; effluent 0.018. Distr. system contains total of 228.7 mi. of pipe, 116 mi. being of 4″ to 24″ sizes; 9.571′ new pipe laid during year. No. of valves, 1,615; no. of hydrants, 958. Per mi. of main, 4.19, ave. spacing, 1,260′; annual rental per hydrant, $35.00. 18,547 meters in service, 1,989 repaired during yr. Total direct operating expense equalled $5.91 per mil.gal., some of items being $0.29 water source expense, $0.24 fuel expense, $0.29 chemicals, $0.63 purification exclusive of chemicals, $0.94 distribution, $1.42 commercial and $1.81 general—total operating expense, $6.80, fixed charges, $10.30, total, $17.10. Recd. per 1,000 gal., $24.63.—*Martin E. Flentje.*

Developments in Canadian Waterworks Practice 1850–1940. Albert E. Berry. Can. Engr. **78:** 12: 9 (Dec. '40). First public water supply system in Canada constructed at St. John, N. B., in 1837. During period under review, no. of public systems increased from 3 to 1,275. Percentage of population served by public supplies in various provinces varies from 18% in Saskatchewan and Prince Edward Island to 64% in British Columbia—for entire Dominion it is estimated at 54%. Population still predominantly rural and hence percentage not as high as in some other countries. Canada's supply of fresh water estimated to be largest of any country in world. Computed that more than half of total fresh water on surface of earth contained in Great Lakes system. Tabulated data regarding percentage of population and of municipalities in different provinces supplied from surface waters show that such sources have been selected by vast majority. Precipitation of satisfactory quantity throughout most of Canada and well distributed over yr. Lack of low-cost coal and abundance of elec. energy from water power have made electrically-operated pumps first choice in Canadian water works. About 3¼ million people supplied by modern gravity filtration plants. 68 gravity mechanical plants, 47 pressure filter plants and 12 slow sand plants. Total pop. served by pressure plants only 225,000, most being located in small communities. In Quebec, mechanical gravity plants only may now be constructed for munic. supply. Recent trend to use coarser sand—up to 0.5–0.55 mm.—in gravity filters; depth of sand usually 26–30″ in. Spiral flow tanks used extensively for conditioning water for filtration. Retention period in settling tanks usually 2–4 hr. Recent plants all equipped with dry feed machines; trend toward gravimetric type where greater accuracy desired. High percentage of water supplied in all provinces except British Columbia chlorinated; in Ontario, more than 80%. All methods of taste control used to appreciable extent. In '39, typhoid mortality per 100,000 was as follows: British Columbia, 0.5; Alberta, 0.9; Saskatchewan, 1.1; Manitoba, 2.2; Ontario, 0.4; Quebec, 3.4; New Brunswick, 2.4; Nova Scotia, 0.5; Prince Edward Island, 1.1; and all Canada, 1.6. Atmospheric temp. varies widely and hence depth of cover over mains ranges from 4′ to 9′. Cast-iron pipe used in high percentage of distr. systems; use of steel cylinder-reinforced concrete pipe for large mains increased in recent yr. Recent survey showed that nearly 50% of mains 6″ in diam. and that ave. of 8.1′ of main required to serve each person. Service pipes chiefly of lead or copper. Ave. no. of services per

mi. of mains, 111, and ave. no. of persons supplied by each service, 4.2. In most municipalities, only one set of mains for domestic, industrial and fire purposes; in some, however, 2 separate systems. Survey of 105 systems showed 45 to be administered by pub. util. comrs. 33 by munic. councils, and 17 by committees or other bodies. Ave. cost to consumer for water supplied to 5-room house assessed at $2,000 is $16 per yr., flat rate. Ave. for metered supplies is $14.45 per yr. Fire protection charges usually based upon no. of hydrants. Charges vary considerably but ave. is $40 per hydrant, $307 per mi. of mains, or 0.723¢ per in.-ft. of mains, and equivalent to 11.9% of total operating charges.—*R. E. Thompson.*

River Water Supply for Moose Jaw, Saskatchewan. A. W. ELLSON FAWKES. Am. City. **55:** 7: 40 (July '40). Shortage of water at Moose Jaw, Sask. eventually brought about initiation of project, in '38, to bring in an ample supply from South Saskatchewan R., about 100 mi. from city. Due to sand carried by river, necessary to construct 500′ crib infiltration gallery below water line along river bank. Water flows from crib to four 2,600 g.p.m. (Imp.) pumps operating against 350′ head, 3 of which will normally be used to deliver water to 68-mi. open canal. 2 miles from beginning of canal, earth filled dam constructed to create res. holding 50 mil. gal. (Imp.). At lower end of canal, a 50-acre saturation area from which top soil was removed, leaving a sand stratum varying in depth from 20′ to 30′, and which is used for water spreading. By means of well points, approx. 3 m.g.d. (Imp.) can be extracted from spreading area for delivery to city. Method of water spreading and recovery by well points is unusual and is first installation of its kind in Canada. ★[Author of article has explained that saturation area is used primarily for water storage to carry city over 4- or 5-month period during which canal is frozen.]★—*Arthur P. Miller.*

Problems Involved in West Lorne Water Supply. MAXIM T. GRAY. Can. Engr. **79:** 2: 11 (Feb. '41). Recently completed water supply system of West Lorne, Ont. (pop. of 1,000), described in considerable detail. Test holes failed to reveal underground water and recourse was had to Lake Erie, 5 mi. south. System includes intake, pumping station, filter plant, supply main and distr. system, including elevated tank. Intake, of 12″ cast-iron pipe, extends 1,150′ into lake; laid in trench 2½–3′ deep and terminates in crib constructed of 8″ x 8″ timbers, in 19′ of water. Pumping station on shore contains 350-g.p.m. pump, equipped for elec. and gasoline-engine drive, which lifts water to filter plant on bank, 95′ above lake level. Treatment plant consists of alum feeding equipment, 4 octagonal-shaped, spiral-flow mixing chambers, providing detention period of 30 min., settling tank, providing 2 hr. detention, and 3 filters. Latter have capac. of 175 g.p.m. each and contain 15″ graded gravel and 26″ sand with effective size of 0.32–0.38 mm., and uniformity coef. of 1.6, max. grain size being 1 mm. Centrifugal pump, taking suction from clear well, supplies water for washing filters. Water chlorinated just before it leaves filter plant. High lift pumping station, which delivers water through 10″ pipeline to village, contains 200-g.p.m. motor-driven centrifugal pump and diesel engine-operated pump of same rated capac. Latter will be used at all times possible. Distr. system consists of about 7½ mi. of 2–8″ pipe. Services of ⅝″ copper pipe. Elevated tank capac. 65,000 gal. Max. consumption estimated at about 300,000 g.p.d., of which Mich. Central R.R. would require 200,000 gal. Cost of project $126,000 and annual cost estimated at about $10,000.—*R. E. Thompson.*

New Sources of Water Supply for Louiseville, Que. RENE CYR. Eng. Cont. Rec. **54:** 10: 14 (Mar. 5, '41). Water supply of Louiseville, industrial town situated on north shore of St. Lawrence R., 80 mi. east of Montreal, derived from 12 springs until '29. Several other parishes also supplied. In '29, new firm located in town and, as springs not adequate to supply additional consumption, intake in "Grande Riviere du Loup" and two 0.4-m.g.d. (U. S.) filters were constructed. Plant built by and belongs to

municipality but operated by company, surplus water, after chlorination, being available for use by municipality. Additional 0.5-m.g.d. filter constructed in '31. In recent survey for additional sources of supply, Maskinonge R., group of 3 creeks, other springs, and wells considered. Underground source adopted and to date, flow of 0.4 m.g.d. obtained. —*R. E. Thompson.*

London (Ont.) Report for 1939. ANON. W. W. Inf. Exch. Canadian Sec., A.W.W.A. **3:** E: 5: 9 (Oct. '40). Ave. daily consumption was 5.8 m.g.d. to estd. pop. of 76,099, or 71.6 g.p.d. per capita. Maintenance and operating costs averaged $64.78 per mil.gal. Domestic bills average $1.00 per mo. and commercial bills $5.43. Total revenue was $377,019 and excess of revenue over operating expense $238,813. All services metered. Ave. cost per service laid $25.67.—*R. E. Thompson.*

Annual Report, Chatham, 1939. ANON. W. W. Inf. Exch. Canadian Sect., A.W.W.A. **3:** E: 4: 7 (Sept. '40). Water supply of Chatham, Ont., serving 17,000, derived from Thames R. Daily consumption 2.2 m.g.d. and per capita use averaged 130 gal. per day. Supply filtered and chlorinated. Ave. dosages of alum and chlorine 7.0 and 14.2 lb. per mil.gal., respectively. Ammonium sulfate used during summer and fall. Turbidity of raw water as high as 1,850 p.p.m. Cost of water per 1,000 gal. $0.0945, while revenue averaged $0.133, giving surplus of $7,618.43 for yr. **Chatham Report, 1940.** *Ibid.* **4:** E: 2: 2 (Feb. '41). Max. turbidity of raw water 1,100 p.p.m., hardness, 375 p.p.m. Alum dosage used averaged 2.05 g.p.g. and chlorine, 13.5 lb. per mil.gal. Ammonium sulfate, 5 lb. per mil.gal., also employed. Ave. consumption 2.3 mil.gal. (U. S.), equivalent to 135 gal. per capita. Cost of water per 1,000 gal. (Imp.) 9.29¢ and revenue 14.2¢. 45 mi. of mains, 269 hydrants, 4,492 services and 4,500 meters in system. Bills rendered quarterly.—*R. E. Thompson.*

Annual Report, Guelph (Ont.), 1940. ANON. W. W. Inf. Exch., Canadian Sec., A.W.W.A. **4:** E: 3: 3 (Mar. '41). Ave. consumption by pop. of 22,602, 3.8 m.g.d., or 168 g.p.d. per capita. Water supply obtained from deep wells and springs chlorinated only. Current expenditures averaged $1.74 per capita. In excess of $5,000 expended for guard duty. Cost of pumping $11.76 per mil. gal., 53.9 mi. of mains, 266 hydrants, 5,909 services and 204 meters.—*R. E. Thompson.*

Welland (Ont.) Annual Report, 1940. ANON. W. W. Inf. Exch., Canadian Sec., A.W.W.A. **4:** E: 4: 4 (Mar. '41). Water supply drawn from Welland Canal and treated at 6-m.g.d. mechanical gravity filter plant. Crowland and Thorold Townships also supplied. Ave. pumpage 2.6 m.g.d., equivalent to 100.5 g.p.d. per capita to population of 17,381. Only 33.2% of water sold by meter. Revenue exceeded expenditures by $10,259.09. Costs per 1,000 gal. as follows: purif., including pumping, 1.56¢; distr., 0.84¢; administration, 0.85¢; debt charges, 2.72¢; total, 5.97¢. Anhydrous ammonia, chlorine (0.775 p.p.m.), activated carbon, alum (0.833 g.p.g.), lime (0.049 g.p.g.) and sulfur dioxide used in treatment process. 24.5 mi. of mains and 270 hydrants.—*R. E. Thompson.*

Future Trends in German Water Supplies. KARL LEMBERG. Gas u. Wasserfach. (Ger.) **84:** 33 (Jan. 18, '41). Technical and economic problems no longer purely calculable and constructive problems; they are national orders in whose center is people and common usefulness. Application of principle requires extension of house water services in small communities and to farms. Farm supplies especially needed to relieve labor needed on farms for carrying water, to reduce health hazards and to decrease fire losses. Such supplies have to be planned on regional basis to get most economical use of available water resources for all that need them. Planning should be done by state offices that have authority to lay out general plans, approve detail plans by private engineers or design them where needed, co-ordinate water projects with industrial and eco-

nomic developments, and supervise operation of existing plants. Organization of Bavarian Water Survey given as model example. Cost of such office given as about 5¢ per capita.—*Max Suter.*

Extension and Safeguarding of Rural Water Supplies. HANS HOLLER. Gesundh. Ing. (Ger.) **63:** 499 (Sept. 28, '40). About 60% to 70% of rural pop. of Germany has no pressure water supply inside house. This should be remedied as phase of introduction of labor saving devices. Type of supply to be selected depends on local conditions. Either individual supplies for each farm, with gravity feed or air tank, can be used, or central supply including fire protection can be installed for groups of houses, villages or groups of villages. Greatest hindrance to installation of central supplies for rural pop. has been found in the presence of local supplies for some richer communities which do not want to take part in central supply. Thereby all costs thrown on poorer places. Type to be used to be decided after thorough study and planning of water resources of a whole region. Study should be made by state organizations with assistance of competent consultants. Should include not only planning of best water supply, but also allow for growth of the community, long time developments, costs and state supervision of safety of supply. Proposed that program for complete provision of rural supplies within 20 yr. be laid out. Estimated that annual cost of such program would be about $30,000,000. —*Max Suter.*

Water Supply in Northern Ireland. R. L. WALSHE. Civ. Eng. (Br.) **35:** 258 (Sept. '40). Scheme for new water works for Belfast City and District Water Comrs. comprises: for low level works 3-mil.gal. service reservoir, rapid sand filter plant with capac. of 1 m.g.d. (Imp.) and ancillary works; and for high level works, 600,000 gal. (Imp.) service res., and about 8 mi. of distr. piping. Larger res. 285′ x 142′ in plan, with depth of 12′. Walls designed as cantilevers with expansion joints in center of each wall and footing. Roof slab designed as flat slab with two-way reinforcement. Filter house constructed throughout in reinforced concrete finished on exterior surfaces with carborundum stone. Entrance hall and lower platform finished in buff-colored tiling with covered skirting of darker color. 6 gravity type filter units, with total effective area of 660 sq.ft. deliver required output of 1 m.g.d. (Imp.), filtering at rate of 80 gal. (Imp.) per sq.ft. per hr. Following filtration, water sterilized, and ammonia added. Pumping station of reinforced concrete, located against side of clear water res., remote from filter house. Duplicate, multi-stage centrifugal pumps installed, each giving delivery of 700 g.p.m. (Imp.) against max. head of 420.5′. Pumps driven by wound-rotor induction motors, automatically controlled through relays at upper res.—*H. E. Babbitt.*

The Water Supply of Scotland. *Extracts from vol. 33 of "Memoirs of the Geological Survey Special Reports on the Mineral Resources of Great Britain."* M. MACGREGOR *et. al.* Wtr. & Wtr. Eng. (Br.) **42:** 375 (Nov. '40). Large quantities of surface water available, actually or potentially, in upland areas. In Midland Valley conveniently situated high ground, suitable for location of reservoirs, very often formed of lava flows of Lower Old Red Sandstone age or of Carboniferous age. Of recent years, both in Highlands and in Southern Uplands, natural lochs and artificial reservoirs at different levels connected by means of tunnels, to provide adequate source of water power for industrial purposes. Supplies of water often obtained from shallow wells sunk in river or marine alluvium, or in glacial sands and gravels that overlie impervious rocks or layer of impervious boulder clay. Rocks that form potential sources of underground water very largely restricted to Midland Valley, where Upper Paleozic strata have been subjected to comparatively gentle folding. Chief actual and potential sources of underground water are sandstones, arkoses, grits, and conglomerates of Torridonian, Lower Middle, and Upper Old Red Sandstone, and Carboniferous formations. Permian, Triassic, Jurassic and Cretaceous

sandstones have very restricted distribution but may be of importance locally. Distribution of boulder clay may be of importance in connection with well sinking for supplies of underground water. Particularly the case in Midland Valley, where impervious surface mantle of stony clay covers much of lower ground. Mineral content of water derived from Upper Old Red Sandstone and Calciferous Sandstone series of Edinburgh has influenced location and development of considerable brewing industry.—*H. E. Babbitt.*

Water Supply at Macclesfield. J. H. DOSSETT. Civ. Eng. (Br.) **35:** 314 (Nov. '40). Pop. of Borough of Macclesfield in '38, 36,340, of whom 34,840 supplied with water. Total consumption, 524.5 mil. gal. (Imp.), or 39.7 g.p.d. per capita. Increased consumption necessitated investigations of further sources of supply. Two 15″ diam. trial boreholes sunk to depth of about 500′ confirmed existence of supply of excellent quality, though containing hardness of 230 p.p.m. Development of sources estimated to cost £130,000. Water raised from wells by electrically operated multi-stage centrifugal pumps. Base-exchange softening plant located at each of two pumping stations to produce softened and blended supply with final hardness of 80 p.p.m. Softeners designed for downward softening and upward regeneration. Filtration plant to consist of 6 horizontal, air-scoured pressure filters designed to filter normal quantity of 96,000 gal. (Imp.) per hr. Alumina-ferric to be injected as coagulant, and small quantity of hydrated lime to be added after filtration. About 8 mi. of trunk main connected with scheme, varying from 15″ to 9″ in diam. Spun-iron pipes in 18′ lengths used with Stanton-Wilson joints. Most of work well advanced in spite of difficulties in obtaining labor and materials. —*H. E. Babbitt.*

East Elloe R. D. C. Water Supply. G. EWART ROBERTS. Wtr. & Wtr. Eng. (Br.) **43:** 40 (Feb. '41). East Elloe Rural Dist. Council administers area of 133 sq.mi. with pop. of 23,400, situated mainly in urban districts. In '36 some 67½ mi. of mains laid and further 53 mi. laid since outbreak of present hostilities. Total capital expenditure now £122,375 and about 19,000 of total pop. are being afforded supply of pure water. Present consumption reaches max. of 400,000 g.p.d. (Imp.).—*H. E. Babbitt.*

Brisbane Water Supply. ANON. Commonwealth Engr. (Australia) **27:** 9: 303 (Apr. 1, '40). Brisbane water-treatment plant has capac. of 4½ mil.gal., which ordinarily consists of rapid gravity or slow sand filtration followed by ammonia-chlorination. For 13 days during '38–'39, turbidity of raw supply was great enough to require coagulation with sulfate of alumina. Ave. dose of 5.3 g.p.g. necessary to reduce such turbidities from raw max. of 3,000 p.p.m. to pre-filter ave. of 250 p.p.m. Under these high turbidity conditions, slow sand filters plugged rapidly. Second precipitant, sodium aluminate, necessary before dosage to rapid filter. For the year, 48.5% of supply passed through slow sand filter which with 13-day exception produced high quality effluent from uncoagulated raw water. Economy practiced closely by using chemicals for as small portion of total water as possible. As to latter, no sedimentation facilities provided when coagulation used only for rapid gravity plant. All floc dosed directly to sand causing rapid plugging. Multilec pH recording apparatus allows close control of alum dosages to rapid filters as well as checking on filter effluent as to corrosiveness of supply to mains. Additional storage believed necessary for plant. To determine effectiveness of such additions, prototype model installed and valuable information expected from its operation as to ways and means of increasing plant efficiency and economy.—*P.H.E.A.*

The Warragamba Water Scheme, Sydney, New South Wales. J. M. ANTILL. Wtr. & Wtr. Eng. (Br.) **43:** 11 (Jan. '41). Existing water supply comes from Nepean watershed, with catchment area of 400 sq.mi. Total practicable storage economically available, 120,000 mil.gal. (Imp.). Woronora Dam, last of big dams on Nepean watershed, still under

construction. Consists of mass concrete gravity structure with height of 217′ above foundation. Ultimate project of Warragamba scheme will provide further storage having 135,000 mil.gal. (Imp.) with safe draft of 210 m.g.d. (Imp.). Full scheme will be brought into operation as follows: (1) 1940—Pumped supply of 40 m.g.d. (Imp.) through 48″ main from temporary weir. (2) 1950—Supply increased to 80 m.g.d. (Imp.) by addition of increased pump capac. and duplication of delivery pipe line. (3) 1960—Further increase in capac. to deliver approx. 150 m.g.d. (Imp.). (4) 1968—Gravitational supply from 300′ high dam, to be located 500′ to 600′ downstream from weir, and to have safe draft of approx. 210 m.g.d. (Imp.) from catchment area of 3,300 sq.mi. Site of weir and of future dam in rugged narrow gorge, 500′ deep, with precipitous sides. River at site is 10′ deep but floods have been recorded giving water depth of 100′. Water conducted from weir through trash grating to 72″ suction pipes, laid in tunnel 1,000′ long and leading to underground pumping sta. From top of pumping sta. shaft, delivery mains run underground to Megarrity's Creek, which is spanned by 178′ concrete arch bridge, 80′ above creek bed. Pipe line then passes through tunnel nearly 1½ mi. long to Nepean River crossing. River crossed by inverted siphon. For present, only one 48″ main being laid but provision made for expansion of scheme. First stage estimated to cost £1,055,000 and will necessitate laying of total of 16½ mi. of pipe.—*H. E. Babbitt.*

Water Supply in Western Holland. Water. (Neth.) **24:** No. 10 (Oct. 18, '40). Rivers supplied in '38 about 58 mil.cu.m. water to 1,300,000 people. With increased use and various other factors, there is danger of salt encroachment. Yssel lake expected ultimately to have surface area of about 750,000 acres with capac. of from 9,700 to 10,300 billion cu.m. Chloride balance indicates that ave. of 230 p.p.m. may be expected under adverse conditions and of 175 p.p.m. chlorides under good conditions. This will not produce taste. Other lakes and ponds have capac. of 240 mil.cu.m. Evaporation estimated to be about 25″ per yr. Chem. composition varies greatly. Many potential supplies polluted. Only limited supply could be used. Water consumption for years 1970 and 2000 estimated to be 272 and 385 mil.cu.m. Dunes may supply 50, deep wells 100 mil. cu.m.; remainder must come from surface supplies. Surface supplies greatly affected by conditions in surrounding countries (pollution, salt concentration, industrial wastes) so international co-operation necessary.—*Willem Rudolfs.*

Water Supply for Amsterdam. Water. (Neth.) **24:** No. 11 (Nov. 1, '40). Future consumption estimated to be 80 mil. cu.m. per year, or about 45 gal. per capita. Lakes and ponds will supply 15 mil.; dunes, 6–10 mil.; and rivers, 55–59 mil.cu.m. To produce water of 100 p.p.m. Cl content, river water must be diluted by transport to ponds and lakes and hence to dunes. By replenishment, dune supply will increase slightly. Purif. of river water proposed along following lines: rapid sand filtration, storage in dunes, filtration (slow sand filters) and sterilization. Hardness of water will be 115–150 p.p.m.—*Willem Rudolfs.*

Annual Report [1939] North Holland Provincial Water System. Water. (Neth.) **24:** 218 (Dec. 27, '40). No. of connections increased from 104,763 to 107,561 (2.7%); quantity of water delivered increased 4.7%. Effect of central water system on public health shown by comparing individual supplies in '05–'09 with provincial supply in '35–'39. Number of cases of *febris typhoidea* per 100,000 in 5 yr. in North Holland 350 in former period and 16 in latter.—*Willem Rudolfs.*

The Water Supply of the Communities of Aesch and Pfeffingen. Canton Baselland. ANON. Wtr. & Wtr. Eng. (Br.) **43:** 9 (Jan. '41). Two communities, in Switzerland, have common water supply. High-level res. has total capac. of 103,500 gal. (Imp.), which includes reserve of 66,000 gal. (Imp.) for fire extinguishing reserve. High lift pump, at res., automatically controlled, operating time being limited to hours when electric cur-

rent is cheap. Second well pump installed in subsoil pumping station as standby unit. Sufficient supply for fire extinguishing obtained by connecting low pressure system to high pressure system. Manual operation of switch-over valve replaced by automatic operation. —*H. E. Babbitt.*

Water Supply of Singapore. *Engr.'s Report on Dept. Work in 1939.* Surveyor. (Br.) **98:** 153 (Sept. 27, '40). Repairs to valves in valve tower at McRitchie Reservoir involved removal of sluice of each valve from body casting. Difficult matter as tower is of "wet" type with valves inside. At Woodleigh pumping sta., total running cost per 1,000 gal. (Imp.) pumped to 100′ head, 1.48¢ (Straits). All water supplied to consumers filtered and chlorinated, at ave. rate of 22.7 m.g.d. (Imp.) at cost, excluding capital charges, of 1.22¢ (Straits) per 1,000 gal. (Imp.). Bukit Timah slow sand filters in use throughout year and, wherever possible, double filtration carried on. Approx. 14 mi. of new mains laid during year. All new fire hydrants made in munic. workshop. 4″ rubber pipe placed in sea in '35 lifted and tested. Major failure is in exposed metal while pipe stands up well. Investigations commenced at Kota Tinggi on Johore R., with object of drawing up scheme for meeting possible future needs when Gunong Pulai scheme fully developed. Drawings in hand for construction of small experimental filter plant.—*H. E. Babbitt.*

Shanghai (China) Water Works Co., Ltd. *Annual Report, 1939.* W. P. Rial. Consumption averaged 53.28 m.g.d., increase of 14.94% over '38. Max. daily demand 65.94 mil.gal. Ratio of ave. daily to max. daily demand 1:1.24 and of hourly ave. to hourly max., 1:1.62. Turbidity of Whangpoo R. water reduced from ave. of 148 to 20.6 p.p.m. prior to filtration with ave. dosage of 0.8 g.p.g. alum. All water applied to rapid sand filters pre-chlorinated, ave. dosage being 0.926 p.p.m. In addn., ave. of 0.394 p.p.m. applied to rapid sand effluent and 0.281 at main engines. Of total output, 28% from slow sand plant and 72% from rapid sand. Ave. rates of filtration 2.01 and 100 gal. per sq.ft. per hr., respectively. Ave. no. of days between cleanings of slow sand filters 14.99 and water used for washing rapid sand units averaged 2.59%. Invasion of some slow sand filters by bristleworms (*Nereidae*) occurred in Nov. Organisms, centipede-like in appearance and 7–9″ long, burrowed into sand to depth of 6″, honeycombing surface. For 3 months, chlorides varied between 100 and 120 p.p.m. Concentration at no time perceptible to taste but industrial processes such as brewing, photography and steam raising adversely affected. Only 2 complaints received regarding taste, and noted that slow filtered water had less taste than rapid sand effluent. Of 1,808 samples of water from distr. system examined for coliform organisms, 97.8% were negative in 100 ml., 1.8% positive in 100 ml., 0.3% in 10 ml., and 0.1% in 1 ml. Cost of pumping per mil.gal.: from river to settling tanks, $6.36; from settling tanks to filters, $9.02; and from filters to distr. system, $36.54. Details given of efficiency and cost of operating individual units. Cost of steam per 1,000 lb. was $2.7423 and B.t.u.'s consumed per lb. of steam produced averaged 1,934. Fuel cost per million B.t.u.'s $1.216, compared with $0.73 in '38. Marked increase in price of coal, electricity, fuel oil and labor during yr. In 258 electrolysis tests, difference in potential between tramway rails and mains exceeded prescribed limit of 2 v. in only 4 cases. Leaks repaired per mi. of main averaged 7.27 and waste inspection disclosed 2,182 leaks. Hydrant maintenance cost $14.55 per hydrant.—*R. E. Thompson.*

Two Colossal Water Supplies. B. F. Van Nievelt. Water. (Neth.) **24:** 213 (Dec. 27, '40). Apulian water system in Italy now practically completed and supplies 299 communities, pop. 2.5 million, over area of about 20,000 sq.km. Water obtained in part from wells about 1,300′ above sea level on western slope of Apenine Mts. Ave. vol. available about 14,400 cu.m. per hr., with max. of 25,200 and min. of 10,800. Main line can carry 22,680 cu.m. per hr., allowing usage of 150 liters per capita per day for 5 large

cities; 110 liters for cities with more than 20,000; 90 liters for communities from 10,000 to 20,000; and 70 liters for smaller places. Tunnel, 15 km. long, forms beginning of main header 244 km. long, of which 108 km. as tunnels; 122 km. as open canals; 7 km. as aqueduct; and 7 km. as double piping. 2 branches lead to province of Foggia and reservoir of Besanese. Secondary branches made from reinforced concrete and asbestos-cement, with about 5′ of cover. Operation pressure is max. of 3 atm. Accomplished by pumping water to communities located at higher altitude than mains; energy produced by drop in main and small water power stations with total capac. of 8,700 hp. Total length of all water lines 2,046 km. 179 reservoirs. Other system described is Colorado.—*Willem Rudolfs.*

INDUSTRIAL WATER SUPPLY

Water Requirement of Industry. D. W. ROBINSON. Southwest W.W.J. **22:** 7: 24 ('40). ★[Excellent, comprehensive, yet brief, survey of treatments for boiler, ice mfr., cooling, bottling plants, breweries, canneries, paper and textile.]★ In many cases numerical limits for various constituents given. Nearly any process used to improve water supply for domestic and commercial uses will also improve it for industrial purposes. Any further treatment for industrial use usually considered to be responsibility of industry requiring special qualities.—*O. M. Smith.*

Removal of Silica From Industrial Water Supplies. S. E. TRAY AND T. L. PANKEY. Combustion. **12:** 5: 39 (Nov. '40). Soluble silica is removed in hot-process treatment using activated lime containing magnesium. Water of 26.4 p.p.m. SiO_2 was subjected to 155 p.p.m. dosage to reduce SiO_2 content to 1.2 p.p.m. in 1 hr. Data on operation of one actual installation for 48 hr. showed continuous reduction of SiO_2 to less than 3.0 p.p.m. Cold-process softening not as effective for SiO_2 reduction as hot. Comparative data for treatment in cold show that ratio of SiO_2 adsorbed to reagent used greater for activated magnesium lime than for ferric sulfate, dolomitic lime or aluminum hydrate, when residuals of 0.5 to 10.0 p.p.m. SiO_2 to be obtained. Survey of representative installations indicates ave. cost of SiO_2 removal ranges from 0.9 to 1.2¢ per 1,000 gal., exclusive of softening. —*T. E. Larson.*

TAPPI Survey of Paper Mill Water Requirements. L. B. MILLER. Paper Tr. J. **110:** TAPPI Sec. 313 ('40). Information on composition of water used in paper industry and permissible upper limits for impurities in such water collected from large no. of factories. Wide range in composition of water used as process water shown in table which gives following figures: turbidity, 0–635 p.p.m., (0–10 p.p.m. for 34 out of 42 factories); color, 0–150 p.p.m. (0–10 p.p.m. for 24 of 45 mills); iron content, 0–4 p.p.m. (0–0.5 for 32 out of 42 mills); hardness, 0–400 p.p.m. generally, and reached 766 p.p.m. in one case; alkalinity by methyl orange titration 0–400 p.p.m. (0–20 for 40 of 43 mills); total solids 50–600 p.p.m. (50–100 p.p.m. for 17 of 36 mills); pH value 5.8–9.2, with majority between 7.0 and 7.5. Information on permissible upper limits fragmentary; evidently little attention given to specifications of quality of process water as far as mineral constituents concerned. Wide variations in data given probably partly due to variety of products manufactured. Upper limits for sulfates in process water range from 7 to 200 p.p.m., chlorides, from 0 to 30 p.p.m., dissolved solids, from 50 to 425 p.p.m., total solids, 75 to 425 p.p.m., and pH value, 6.0 to 7.6. Planned to continue investigation until useful set of specifications on process water developed.—*W.P.R.*

The First Bleached Sulfite Pulp Mill in the South. ANON. Pacific Pulp & Paper Ind. **14:** 10 (Feb. '40). Approx. 25 m.g.d. supplied by 5 wells 1,100′ deep

and 2,200′ apart. H_2S removed by 30-m.g.d. tray-type degasifier. Upper ½ inclosed and supplied with scrubbed flue gas. Lower ½ open for escape of H_2S with CO_2 absorbed in upper portion. Degasified water falls into 1¾-mil.gal. covered concrete reservoir kept ¾ full by float-controlled well pumps. Boiler makeup softened with $Ca(OH)_2$ and $NaAlO_2$ in an "Accelator". $Ca(HCO_3)_2$, $Mg(HCO_3)$ and SiO_2 reduced. "Accelator" effluent clarified by 3 anthrafilt filters, recarbonated and softened in 3-unit automatic "Zeo-Karb" plant. Anthrafilt and Zeo-Karb insure min. SiO_2 in effluent. Sea water for regenerating and backwashing zeolite and "Zeo-Karb" is pumped from Amelia R., chorinated, coagulated with alum and clarified by 3 horizontal pressure filters. Elevated, 100,000-gal. sea-water tank floats on line. ★[In addition to 1½-m.g.d. "Zeo-Karb" plant, 10-m.g.d. automatic zeolite plant also regenerated with sea water.]★—*John Lester.*

Industrial Water for the Textile Industry. II. L. Schwabe. Klepzig's Textil-Z. (Ger.) **43:** 421 ('40). To determine total hardness, shake measured volume of water thoroughly with 2 drops bromothymol blue solution. If water becomes greenish yellow, titrate with 0.1 *N* potassium palmitate solution until it becomes bluish green; if water is green or blue, render it first yellowish green with hydrochloric acid before titration. To determine carbonate hardness, to 50 ml. water, add 2 drops methyl orange solution and titrate with hydrochloric acid solution of strength of 48.85 ml. of *N* acid in 1,000 ml. of distilled water. Tables show: (1) comparison between German, English and French degrees of hardness; and (2) weight of acetic acid required to render water of various degrees of hardness suitable for dyeing purposes.—*C. A.*

The Use of Water in the Production of Petroleum. K. R. Teis. Southwest W.W.J. **22:** 10: 17 ('41). Demand for water varies widely from well to well and from few hundred barrels to several thousand barrels per drilling day. Quantity of drilling water for rotary drills large and only for short duration; quality need not be good. Plant must be constructed so as to be mobile or of readily salvageable conduits in distr. system. Drilling operations, of necessity, carried out in haste; hence adequate supplies must be developed rapidly. Water for water-flooding must be free from suspended matter and from unbalanced concentrations of mineral salts which might plug oil-bearing sands. Water high in salt to be injected into subsurface formations are aerated to remove H_2S and CO_2, stabilized by contact with $CaCO_3$ sludge, settled and filtered. In some cases brines filtered and treated under pressure without contact with air. —*O. M. Smith.*

Santa Fe Improves Water Supply at Shopton, Iowa. Anon. Railway Eng. and Maint. **35:** 5: 305 (May, '39). Although Shopton (Fort Madison), Iowa, terminal of Atchison, Topeka and Santa Fe R.R. located immediately adjacent to Miss. R., serious trouble experienced in obtaining dependable water supply. Maintenance difficulty with intake well installed in 1898 at river and 14″ suction line to pumps in power house made it necessary to augment supply in '08 by purchasing city water. In '12, 12 small-diam. wells installed on shop grounds, which increased supply 600 g.p.m. but the fine water-bearing sand soon become clogged. Pool formed by Keokuk Dam built in '13, resulted in depositing silt in original intake well causing abandonment in '17. Similar trouble experienced with new intake well and in '24, 20″ cast-iron intake line installed serving until '36 when silt deposits reached level of 2′ over strainer. In Dec., '36, rotary drilled well completed, cased with 14″ pipe to 146′ and 10″ pipe to 282′. Fine water-bearing sand encountered from 47′ to 136′ and through lower 35′ of stratum, 14″ casing perforated with slots ½″ x 4″. Two 12″ holes drilled through hard clay stratum to 47′ on opposite sides of well for admitting coarse gravel. Well pumped with air from 180′ level and fine sand removed to require replacement with 80 cu.yd. of coarse gravel. Delivery secured was 1,000 g.p.m. with 67 lb. air pressure and test in '38 after 2 yr.

continuous pumping showed no decrease in production. Water collected in masonry res. before treating and pumping to distr. system. Cost of well and gravity line to res. reported to have been $9,461 and operating cost $0.0035 per thousand gal.—*R. C. Bardwell.*

The Present Status of Water Technology in the Fat Refining and Chemical Industries. H. KIRCHRATH. Seifensiederztg. **56:** 368 ('39). Outlines purposes of purif. Include removal of coarse and colloidal suspended matter, softening, and removal of undesirable constituents such as iron and manganese. Softening may be carried out by precipitation processes, e.g., treatment with lime-soda, soda, barium salts, or alkali phosphates, or by ion-exchange processes. Recovery of fats from sewage is discussed. Fats in sewage are of various kinds and include animal fats from slaughter houses, fat refineries, etc., partially saponified oils from factories concerned with mfr. of oil products, edible fats and oils from large kitchens, lubricating and other oils from industries, saponified fats and oils from laundries and textile mills, and wool fat from wool mills. In most sewage works, fats digested and converted to gas. Author estimates that 55,000–60,000 tons of fat per year could be recovered from sewage in Germany (including Austria and Sudetenland). Grease traps, placed where sewage changes its direction of flow, will remove over 90% of floating fats. Reference made to various methods for recovering fats. In Penschuk-Schilling process, direction of flow changed several times, and advantage taken of flotation of fat. Other materials removed with fat by this process, and fat has to be separated by extraction with solvents, or by heating with dilute sulfuric acid. Wool-washing waters may be treated directly with sulfuric acid. Fatty acids precipitated as calcium soaps recovered by treatment with hydrochloric acid. Potash can be separated from fat in waste waters by centrifuging. —*W.P.R.*

Water Problems in Sulfur Production. J. B. CHATELAIN. Tex. W. W. Short School. **22:** 94 ('40). Hot water used for melting sulfur and carrying this sulfur from wells to surface must be treated for removal of scale, corrosive properties and turbidity. Oxygen in water caused formation of rust, accompanied by severe pitting and loss of capac. This reduced to 2 p.p.m. by use of sodium sulfite in doses up to 0.5 p.p.m. and by vacuum de-aeration. Mixed well water containing some calcium and sodium bicarbonate and bayou water treated with soda ash to excess of 45 p.p.m. and hydrated lime, leaving excess of 60 p.p.m. as $CaCO_3$ and 0.15 lb. of copperas per 1,000 gal. to aid coagulation, then settled and filtered. Lime-soda softened boiler water treated very successfully with sodium phosphate in cold, settled and filtered. Only 90% of theoretical amt. of phosphate required to give needed excess of phosphate in boiler blowdown. Mud balls and sand growth eliminated. SO_2 used to adjust sulfate-alkalinity ratio. Waste water freed of H_2S gas by atmospheric spraying, dilution to permit oxidation and dilution with aerated water.—*O. M. Smith.*

ADMINISTRATION, PERSONNEL AND PUBLIC RELATIONS

Good Management Practice. J. B. DANNENBAUM. Tex. W. W. Short School. **22:** 49 ('40). Continuity of service and freedom from political favoritism are foundation upon which to construct framework of good management practice. Efficient employees should be protected by civil service or supervised by non-political boards. Public should be educated, through any civic outlet, to importance of water supply. *Discussion.* J. L. HORNER: Advocates use of suggestions on human relations in Dale Carnegie's book.—*O. M. Smith.*

Long Term Planning of Water Works. TERRELL BARTLETT. Tex. W. W. Short School. **22:** 73 ('40). Most profitable use of foresight is to educate communi-

ties to importance of long-term water system planning based upon best facts available rather than surmised. Little public gain accomplished if constant changes in administration and management overlook, discard, or ignore completely-made layouts and policies.—*O. M. Smith.*

Water Board as Factor in Water Department Management. W. D. MASTERSON. Southwest W.W.J. **22:** 11: 15 ('41). Plan as used in San Antonio, Tex., has proved satisfactory, efficient and economical. Overlapping of membership, 1 member being appointed each year. Serves part time at reasonable small salary making position matter of honor and civic duty rather than profit to individual. By law, board prohibited from giving free water or special rates except to city bldgs. and institutions. Rates must be ample to provide for depn., replacements or extensions. No monies can be diverted to other munic. purposes.—*O. M. Smith.*

The Water Superintendent as an Administrator. A. P. HANCOCK. Tex. W. W. Short School. **22:** 45 ('40). To overcome political favoritism, establish highest possible standards of intelligence and efficiency by seeking licensed operators with high grades, maintain qualified personnel by requiring constant attendance at water works schools, A.W.W.A. and local meetings. Keep silent partner, the public, adequately and truthfully informed by taking advantage of every opportunity to place activities of dept. before it, i.e., newspapers, civic organizations, club participation in all public celebrations, etc.—*O. M. Smith.*

Are Lenient Collection Policies Profitable? JOHN A. WILLIAMS. Edison Elec. Inst. Bul. **8:** 581 (Dec. '40). One end of scale, deposits from customers and payment within 15 days or discontinuance of service; other end, no deposits, payment at convenience of customer, discontinuance after hopeless delinquency. Prudence dictates middle course, considering less liability of misunderstanding if account paid promptly. Experience shows lenient policy improves customer relations and saves money. Deal with customers as individuals, instead of dealing with public. Deposits eliminated in residence districts, then no implied questioning of customer's ability to meet obligations, except in transient areas and where record shows customer a liability. Commercial accounts based on credit rating and probable use. Deposit interest, accounting and handling costs substantial. Unless expensive records kept, delinquent notices go to chronic as well as occasional delinquents. When notices discontinued, collections held up just as well. Obviously, there comes a time in some cases when collection action must be taken. This, however, handled on merits of each individual case. Customers keep definite promise to make payment in more than 80% of cases. Economic conditions also factor. Discontinuance of collection notices makes saving, which is very much worthwhile from net earnings standpoint; even without reduction in expenses, liberalization desirable.—*Samuel A. Evans.*

Inflation and the Outlook for the Utilities. R. MORTON FULLERTON. Pub. Util. Fort. **27:** 330 (Mar. 13, '41). Real inflation unlikely, but rising costs and money rates are due and will present serious problems. Considerable hardship will result if utility rates are lowered. Defense requires expansion, so, for emergency, moratorium or reasonable regulation of rates should be substituted. Public's definition of inflation and not economist's now prevalent; anything that contributes to rise in costs, prices, wages or money rates now regarded as inflationary. Long way from economist's more rigid conception of inflation as something pertaining to money, as, for instance, devaluation or "more rapid rise in supply of money than in production of goods." What is to be done if threat of rising costs materializes? Will present financing plans under consideration be undermined by rising interest rates due to demand for capital for defense industries? Will higher wages, taxes and costs squeeze industry between fixed rates and rising expenses? Will govt. financing and necessary interference with

normal production upset market for private bond offerings? All these questions are related, and bear on problem, and answers will affect industry in near future. Change of U.S. from debtor to creditor after World War, caused downward trend of prices and rates. Rise in bond prices in past 2 yr. and in last 3 or 4 mo. favorable conditions for refunding and new financing, due to phenomenal rise in deposits caused by "refugee" money. Basic tendency of both prices and money unquestionably still down; violent interruption in trend may be caused by dominance of rearmament program. If so, new plants will cost more and money rates will be higher. Talk of rigid war economy appearing on horizon; inauguration of priorities matter of time; labor demands increasing; and utility industry warned of possibility of revising accounting methods if permitted to raise new funds. Loans to Britain unquestionably raise money rates. Govt. has power to keep things in hand, without receiving additional authority from Congress; it could not, however, equal record of France under Reynaud. If rearmament allowed to develop naturally and without interference, costs of metals, bldg. materials and other materials used in defense industries, and price of money would unquestionably rise. Govt. today does not have complete power to control costs; until country decides otherwise, powers limited. By direct action or manipulation of fiscal policy, however, it can give impetus to, or hinder, price trend and conditions for new financing. Administration appears divided on methods to control inflation. One side—Eccles—has always advocated compensating monetary policy and now apparently believes easy money program should be reversed. Other side—Jones, R. F. C.—it is alleged, states money rates too high. Morgenthau seems willing to let Congress call plays. Problem of raising money, however, probably puts him in Jones camp. Author willing to forecast that low coupon bonds now being sold will eventually be refunded at even lower rates. If Congress decides on hard money policy, should stiffen money rates, which seems to come with acceleration of rearmament. Result higher financing costs for industry coupled with rise in wages and construction, and utilities are in unenviable position if forced to absorb any further rate cuts. Utility securities, as a group, still most attractive in private field. Real danger appears to be, not inflation, but deflation in period of mixed price trends. Costs of construction and wages sure to rise. Considerable hardship can be caused by pressure for rate reductions in period of rising prices.—*Samuel A. Evans.*

The Role of the Employer in a Public Ownership Battle. ALFRED M. COOPER. Pub. Util. Fort. **27:** 537 (Apr. 24, '41). Ownership question primarily one of public relations, for public attitude largely influenced by citizen's contact with utility serving his city or dist. Management of any privately owned utility, now feeling pressure of public ownership ideology, will do well to give careful study to morale of personnel. Public largely bases estimate of utility upon rates, physical service and personal employee service. Morale of force great item; goes deeper than courtesy at cashier's window and complaint counter. Management must be whole-heartedly in fight, otherwise attitude will trickle down through organization. Any effort expended to insure high morale will pay excellent dividends at all times in improved public attitude.—*Samuel A. Evans.*

Canada's Unfair Tax Exemption of Public Owned Utilities. LAURENCE B. JACK. Publ. Util. Fort. **27:** 462 (Apr. 10, '41). Virtual tax exemption of publicly owned utilities in Canada disadvantage to privately owned, which are under tax burden. In Sweden, Denmark, Holland, Germany, and Britain public ownership never developed at expense of private industry. In these countries publicly owned utilities called upon to contribute to govt. costs. Trend of taxes levied upon private util. corps. since '30 steadily upward. In Que. utils. taxed more heavily than any other form of business or property. True, taxing of publicly owned utilities would pass to customers. Chief contention is

they have avoided their full share of govt. costs as compared with customers of privately owned utilities. One publicly owned utility cited in particular in making comparisons. Numerous tables and statistics cited.—*Samuel A. Evans.*

Land Values in Relation to Planning and Housing in the United States. RAYMOND UNWIN. J. Land and Pub. Util. Econ. **17:** 1 (Feb. '41). Due to rapid development of U.S. in 19th Century, land values more fictitious than real. In recent years of 20th Century, however, capital values of extensive areas have not increased in greater proportion than incomes yielded; also increase in pop. by immigration and nature has not been proportionately as great. Total land value in sight becoming more limited, consequently must be more evenly distributed. Scarcity of value given fresh importance to relation of density of building to concentration of value, and on extent to which high density tends to locate total available on few favored plots at expense of general body of plot owners. Chicago's pop. ratio diminishing for years. Declining area increasing yearly. Central area of 44 sq.mi. now classed as definitely blighted, entailing huge loss to city. Present value of deferred realization of increment diminishes at rapid rate as period extended; thus, development of whole city area would not counterbalance blighted area in period short of century or more, depending upon rate of growth of entire city. Chicago's pop. increase in recent years slight; from '11 to '30, approximately 60,000 yearly, requiring about 15,000 dwelling units. Assuming recent decentralizing trends reversed and rate of increase recovered, years required to realize value from residential use over the 44 sq.mi. would depend upon density adopted. If 100 families per acre, as in some New York schemes, were adopted, 187 yr. would be required to fill the 44 sq.mi. at increase of 60,000 hereinbefore noted. Effect of density in relation to commercial bldgs. not so easy to calculate. Effective demand for office, warehouse and store purposes will occupy less and less land area in proportion as business premises are built up in stories instead of side by side. General adoption of higher bldgs., coinciding with diminishing rate of general expansion, shares responsibility for prevalence of blighted areas around business centers of many American towns. Value of land for 2 main useful purposes: (1) production for use or enjoyment whether food, game, raw materials or precious metals; (2) sites for dwellings, industries and commercial or social activities. Value consists of what folks are willing to pay for use of land—human psychology—and on whether it will pay to use the land at price demanded—tangible. If land not used, or bldgs. not erected thereon, no real land value exists, only hoped-for value of owner exists, as is case of clerk who wants loan on pay increase he hopes to receive next year, if anyone will share his optimism. Rapid development of pop. and urban centers in last century conferred unreal appearance of actuality on such speculative values; limits not realized. Tendencies carried into present time, when pop. increase has become both small and diminishing factor. Seems that urgent reason exists for citizens of American cities, and land owners, to adopt greatly reduced density of development accompanied by reduced price for unit of land, which, realized on larger area, would yield greater total value, and redeem blighted areas, which would be much more likely to arrest drift of pop. from areas and secure their permanent occupation. ★[Strongly recommended that designers, developers and planners of new or additions to present water systems procure and read, in its entirety, this article.]★—*Samuel A. Evans.*

State Permit Insufficient for Hydroelectric Project. ANON. Pub. Util. Fort. **27:** 508 (Apr. 10, '41). Federal Power Com. ruled that Conn. R. navigable and federal permit necessary for constr. of hydroelectric project. Com. stated in part: "Even though state has granted permission to full extent of authority, nevertheless constr. of character here involved on navigable waters of U.S. requires permit by competent federal authority. . . ."—*Samuel A. Evans.*

Customer Relations. D. J. TUEPKER. Southwest W.W.J. **22:** 10: 27 ('41). Public utility industry has more difficult job in respect to customer relations than any other lines of business, as activities carried on in home directly dependent upon mfr. of water, gas, and elec. service. Customer cannot work, read, play or entertain friends if these fail. Actual physical connection between company and customer via pipes and wires and this raises delicate problem regarding handling of credit. Customer complaints should be handled only by employees who have received special training for this work and never by new member. Analysis of 500 complaints showed 290 were about high bills, only 18 requested that meter be tested, which indicates that most customers are not concerned with accuracy of meters; 59 experienced difficulty with operation of some appliance. Majority of high bill complaints come from customers whose bills increased perceptibly in one mo. over preceding mo.; 99 complaints about radio service, 7 about treatment from company employees, 18 about bulbs burning out too soon though no accurate check had been made on actual burning life of bulbs, 10 because of error in address, and 11 wanted trees trimmed. Another study showed that less than 2% of all people who came into the office actually came in to complain, and of this 2%, only one out of every 75 was caused by actual error on company's part. Complaints take monotonous pattern that becomes too familiar, but back of this is individual and satisfactory service, which require more than usual amount of thought.—*O. M. Smith.*

ACCOUNTING AND FINANCING

On the Understanding of Accounting. JAMES L. DOHR. J. Accountancy. **71:** 200 (Mar. '41). Acctg., until recently, written up largely in terms of development of instrument of administrative control. In past, accountant has provided management with essential information for intelligent direction of business activities. In last two decades, needs of security holders have developed. Average holder has only limited understanding of financial statements. Acctg. largely mathematical, and many not inclined mathematically, lacking in thought concentration, cannot grasp realism inherent in acctg. philosophy, or lack necessary background and training. Accountants have used mathematical device to prove accuracy of their accounts, equilibrium of debits and credits. Device has affected accountant's philosophy, no matter what nature or size of business, finances shown in same balanced status; occasionally an otherwise rational accountant shows losses or assets to satisfy passion for balance. Conventional balance sheet mystifies laymen because its equilibrium is largely without significance. Financial position matter of financial resources vs. financial obligations. Important to show financial status of stockholders as owner; stating their financial position from equilibrium viewpoint unenlightening. Statement form of balance sheet better than account form. Deduction of liabilities from assets rational presentation. Except in isolated cases, not possible to show value of business by balance sheet. Present value of enterprise as entirety usually quite different from sum total of present values of constituent parts. Net worth section of balance sheet misnomer. One basic purpose of balance sheet to show ability to meet current obligations. Balance sheet reflects total economic capital invested, after deductions for borrowed capital and other deductions. Balance sheet includes heterogeneous group of items on common value basis—money, which is variable in purchasing power. Accuracy of balance sheet often illusory, being expression of opinion. Laymen regard acctg. terminology as unsatisfactory, many terms non-descriptive or mis-descriptive. Capital, for instance, applied to fixed total assets, assets less liabilities, and proprietary capital. Capital could be limited to economists definition, using wealth to produce wealth. In presenting assets, cost unquestionably important; if hold-

ing company has investments costing $40,000,000, with present market value of $1,000,000, this is highly significant and should be presented. Valuing assets at $40,000,000 is ignoring most significant fact. Such showing not due to improper acctg. rules, but failure to apply rules intelligently. Understatement may be just as misleading as overstatement. No wedge may be properly driven between acctg. entries and financial facts, as concession to expediency or otherwise.—*Samuel A. Evans.*

Basic Concepts of Property Accounting. W. A. PATON. Edison Elec. Inst. Bul. **9:** 93 (Mar. '41). In acctg., interest is in economic attributes of property rather than physical characteristics. Accountants interested in physical facilities primarily because they represent potentialities of economic service. Necessary for administrative and other purposes to associate cost with physical layout or setting. Cost of any physical body summation of service costs in its process of fabrication and installation; going concern also a cost, although not in physical property. Plant accounts important—especially in utility field—in manner in which such costs are absorbed against revenues in measuring net income or loss. Adequate depn. acctg. requires property cost subdivided as to terms of use, length of life and other characteristics. In utility field, proper classification essential to promote sound property and depn. acctg. Special difficulties encountered, however, in carrying out ideal program of property acctg., in which each charge goes orderly to property acct. Keeping of separate records of yearly installations of types of property, averaging, first-in first-out assumption, and other statistical devices would give reasonable approximation of cost of facilities actually in use. Some accountants think that, if multitude of units is involved, classification and depn. acctg. can be ignored. Much maintenance in past should have been called depn. and accrued in more systematic way as depn. Changes, however, should be reasonable, and made consistently, with due regard to water that has gone under bridge. Depn. acctg. process of assigning plant costs to revenues. Simple methods of periodic assignment advocated, which in this connection is one of appealing features of straight-line depn. procedure. Depn. continues in spite of time; losses exist even though operation is suspended. Utility business not conceived as contractual relationship among public, company and regulatory body. Not guaranteed—still a business with risks. Regulation does not guarantee return.—*Samuel A. Evans.*

Functional Accounting and Simplification of Internal Reports. L. P. SPACEK. Edison Elec. Inst. Bul. **8:** 561 (Dec. '40). Functional acctg., as a system, new, and probably used by few utilities though underlying principles have always been basis for operation of utility properties. Functional acctg. defined as system whereby field activities reported to accountants by predetermined standard descriptions without attempting to state to which acct. chargeable as under uniform system of accts. Operating organization regards acctg. as unproductive burden. Acctg. a device that reduces all utility activities to common denominator—dollar. Activities can then be compared which would be impractical in terms of physical quantities. Primary function to furnish management adequate and pertinent information for intelligent and efficient operation of business. In last decade, reports for external purposes have become large factor. First responsibility of acctg. is to business; functional acctg. rests on this principle. Generally, operating heads determine information required; accountant examines to see if it meets required purposes for reports, regulatory and tax purposes. In practically all cases required information is such that all acctg. reports can be produced therefrom. Functional acctg. eliminates sub-acctg.—analysis of costs for supervisory and executive personnel and concurrent analyses and records in operating depts.—by reporting all costs on basis which shows work performed and who is responsible for it. Functional acctg. summarizes costs by field activities, thus eliminating effort spent reviewing and assigning acctg. distr. All acctg. work

performed in acctg. dept., thus relieving operating depts. Control of distribution by chief acctg. officer under functional acctg. provides rigid control over cost distr., and uniform application. Reports observing departmental lines, aid effectiveness of budget system, by simplification. Utilities, having common ownership, aided by having operating reports on acctg. basis related to organization and personnel of individual companies. No standardized method of installation as it is based on adaptation of acctg. to operation requirements. Might not be advisable for small companies. Functional system of acctg. has numerous benefits due to creating a basic record of what was done and who was responsible for it.—*Samuel A. Evans.*

Accounting Eugenics. JOHN T. MADDEN. Edison Elec. Inst. Bul. **8:** 555 (Dec. '40). Eugenics is science of improving human race by application of known laws of heredity. All change not progress; whether proposed changes in public utility acctg. are progress depends upon viewpoint. Dysgenics defined as study of racial degeneration; aboriginal cost perfect example of dysgenic acctg. Proponents of aboriginal cost urge its use as aid to regulatory bodies in determining fairness of return in future rate controversies. What you do in reconstructing your accts. in past, present or future by re-acctg. or reclassifying allegedly for benefit of posterity. Past is gone and whether economic organization made loss or profit, nothing can be done about it. Aboriginal cost acctg. destroys historical integrity and continuity of acctg. process for purposes of acctg. company; and general philosophy of relation of govt. to business, from which this mongrel sprang, has already gone long way in destroying incentive to good management in utility industry. Science first reduces problem to most elementary form. Confusion and turmoil resulting from innovations in public utility acctg. dictated by govt. could be reduced by understanding that real differences are differences in ends sought. Minor differences will resolve themselves as soon as envisioned ends are achieved or not. Aboriginal cost is wooden horse of prudent investment theorist. Under strict application of investment principle, utility should be allowed return on unreturned dollars, unrequited investment, whether the property is in existence or not. Retroactive determination of depn. on straight-line basis, whether company has collected from customer or not, is inconsistent. Entire accrued depn. to be deducted—if in arrears—by lump charge to surplus. Injustice is still injustice; unfairness and unethical conduct are still injustice—even if covered by mantle of regulation. Perhaps courts or legislators may be relied upon to protect investing public who had right to relay upon what was law of land in making their commitments.—*Samuel A. Evans.*

The Increasing Hazards in the Practice of Accountancy. A. L. BLUME. J. Accountancy. **71:** 206 (Mar. '41). Profession beset with personal liability, yet work of exacting and meticulous character. Volume of ligation in field of accountant's liability has been increasing for more than a decade. Law in this respect constantly changing and accountants should be conscious of their legal responsibilities and govern themselves accordingly. By virtue of holding himself out as auditor, accountant assumes liability for losses sustained by client and absence or failure of his skill regarded as negligence. Lack of such form of skill may be negligence in one case and not in another. Contract under which he is employed determines liability, or extent and purposes of audit may limit or extend responsibility. Liability for negligence may not be restricted to accountant's client, as, if fraud exists, accountant may be liable to all who may be injured by his audit. Courts generally define negligence as "failure to do what reasonable and prudent person would ordinarily have done under circumstances of situation, or doing what such person under existing circumstances would not have done." Thus if accountant's negligence is of some degree, such that where the passion and prejudice of jury are frequently controlled by skillful lawyer, such negligence might be cause for action for

damages by party other than accountant's client. Lower court ruled in favor of defendant accountants that plaintiff could not recover for negligence on part of accountants since their conduct was not such to raise inference of fraud. Majority of appelate court rejected verdict. "Strike Suit"—another plague of accountant is action commenced without scintilla of substance, extorting, under guise of settlement, amount from auditor so that he will not be subjected to unfavorable and possibly harmful publicity. Securities Act of '33 greatly increases accountant's liability, where omission of fact required in registration statement subjects accountant to suit. Burden of proof under sections of Act placed upon accountant to prove that plaintiff was not misled by any untruth or omission, etc. Depending upon amount of securities issued, accountant may be liable for large sums. To eliminate necessity for paying damages, accountant will require protection, by insurance, for himself and his work. Risk of loss considerably higher than formerly. Best protection, to convince courts by vigorous defense against unjustified claims, that accountant's opinion on financial statements does not justify heavy burden of liability imposed. 28 actual cases of asserted claims against accountants, indicating various situations, summarized.—*Samuel A. Evans.*

Cost Accounting for the Water Department. M. C. Fox. Southwest W.W.J. **22:** 12; 15 ('41). No true cost acctg. can be had without correct general acctg. Cost acctg. as applied to units may be accurately developed wherever general acctg. system properly installed and maintained. Eng. and acctg. depts. should co-operate wholeheartedly to use any system successfully and to be able to develop statements and reports which can be understood by ordinary businessman after he has become interested enough really to study them. *Manual of Water Works Accounting* highly endorsed.—*O. M. Smith.*

Regulatory Aspects of Depreciation. Nelson Lee Smith. Edison Elec. Inst. Bul. **8:** 567 (Dec. '40). In discussions of depn. sometimes great stress laid upon minutiae of accrual methods, asymptotic determinations of adequate and proper reserves, actuarial equations to produce survival ratios and mortality curves, so it is advisable frequently to return to review of basic concepts and perspective of its relation to entire public utility picture. Utility depn. not an end, simply a step in operation and regulation of public utilities. Why are some of regulatory agencies stressing depn. studies in connection with analyses of fixed capital and historical or original costs? Depn. difficult to define and measure, but very real and important element of cost in practical business sense of expense and underlying economic concept of production cost. Conflicts between consumers and stockholders ultimately tend to converge. Depn. should be defined and measured as accurately as possible. Evidence is that regulatory bodies are now resolved to determine facts, if possible. Depn. should be reflected in operating expense as accurately as possible and on basis of best factual data available. Reasons for supposing that rate-base determinations will be influenced increasingly by considerations of original or historical cost; therefore, commissions must endeavor to provide that acctg. be as accurate and consistent as is feasible. If assets have suffered depn., commissions cannot validate securities to total amt. of original cost of property. Important to consumer, utility and regulatory body that rate of accrual and status of reserve be as sound as possible. Use of depn. funds for construction or debt retirement may improve debt ratio and increase interest coverage and equity; thus financial position stronger. With better understanding as to underlying nature and course of depn., not common sense to expect utility to be able to claim high depn. for tax purposes, low depn. for valuation and something else for purposes of income. If rates based on something approaching net investment—prudent or otherwise—clear case for deduction of accumulated book reserve. Otherwise commissions will probably not sanction higher rates

of accrual than in past, which may necessitate increased service rates. Many of difficulties due to improper definition terms the outset. National Assn. of Railroad and Utilities Comrs. definition: "Depn. signifies expiration or consumption, in whole or in part, of service life or utility of property, resulting from action of one or more of forces operating to bring about retirement of such property from service."—*Samuel A. Evans.*

Contingent Liability Under Policies With Mutual Insurance Companies. *Auditing Com., Am. Inst. of Accountants.* J. Accountancy **71:** 307 (Apr. '41). Should businesses carrying insurance with mutual insurance companies indicate, under contingent liabilities on balance sheet, that company is subject to assessment under insurance policies? Information is from Am. Mutual Alliance, assn. of mutual insurance groups, operating in fire and casualty field. Except for farm companies operating in limited territory, very few mutual insurance companies in general field which carry unlimited-assessment provision in policies. State- and nation-wide operating companies issue non-assessable policies or limited-liability policies carrying provision of 1 yr. additional premium assessment. Of companies active in '40, only 10 in general class have levied assessments since '00, highest equal to 1 yr. premium. Deposits required to be made by insured, which ordinarily cover several normal year's losses; likelihood of insured paying out any amount of cash remote. Com. concludes no necessity for entry on balance sheet.—*Samuel A. Evans.*

Self-Insurance by a Municipal Water Utility. J. A. JACKSON. W. W. & Sew. **87:** 408 (Sept. '40). At Portland, Me., water dist. sets aside reserves equal to premiums chargeable by insurance companies for injuries, damages, and accident liability. Savings over 24 yr. were 62%. Detailed financial records are included in article.—*H. E. Hudson, Jr.*

Common Stock Financing for the Utilities. FERGUS J. MCDIARMID. Pub. Util. Fort. **27:** 515 (Apr. 24, '41). In many cities investor cannot buy common stock in local utility, because stock is owned by holding co. Result of system of financing which seems undemocratic. Beginning after American Revolution, trend of times was development of joint stock co., subscribers voting their stock. Funded debt and non-voting preferred stock came later, corporate bond issue developed in America after Civil War. System of finance, where great bulk of invested capital is non-voting bonds and preferred stock, and voting common stock small part, is situation too frequently encountered in utility industry. How much capital of public utility co. should be mortgage bonds, common stock, debenture bonds or preferred stock, or holding co. controversial matters, intensely debated. Survey made of 344 major cos., other than utilities and railroads, total stated capital and surplus over 23 billion dollars, less than 11% represented by funded debt at end of '39, less than 33% had any funded debt. Briefly, funded debt 10.7%, preferred stock 11.8%, common stock and surplus 77.5%. Information seems to indicate very great preference on part of American industrial management for equity as opposed to debt financing. Legally restricted financial institutions, as insurance cos., not being allowed to buy common stock, probably put pressure on utilities to sell bonds. Investment bankers and financial journal editorials have stated utility common stocks not marketable satisfactorily under recent conditions. 7 large utilities, for entire group, common stocks have been selling in range which would not preclude possibility of further equity financing. Market prices have tended to run higher than equity and par values. To conservative investor, in holding co., towering pyramid of senior securities robs common stock, at bottom, of all true investment status. Often grave doubt whether common stock has any real equity behind it, if properties behind it be valued at original cost less proper depn. People not liable to put great deal of money into utility stocks until more security of their being sound investments. Common stock should represent really substantial part of total

capital structure; not too idealistic to have 40% bonds and 60% common. Proper sinking fund in connection with bonds would tend progressively to increase equity behind stock. Another feature likely to augment investment status of utility equity securities is simplicity in capital structure, common stock not backed by other pieces of paper, but directly by tangible working properties, with only one set of prior claims intervening. Preferred stock, with little funded debt outstanding, as secure as strong bonds. When preferred stock squeezes out common it becomes harmful, common stock only a small layer at bottom, whereas for stable financial structure should be largest of all. In evaluation of stock of industrial co., earnings are everything, property value almost nil. Property value may place upper limit on value created by current earnings. In case of purchase of private utility by public authorities, property value of supreme importance to common stock holder. Present regulatory trend is to regard original cost of property less reasonable depn. as fair value thereof. Purchaser of utility stock should be sure that earnings are not inflated by insufficient depn. allowance. Federal income taxes on earnings now favor heavily bonded utility. If and when gross revenue levels off, and net starts to decline, no longer possible to sell equities to public. Amt. of time remaining to industry to put its financial house fully in order may be less than one would like to imagine.—*Samuel A. Evans.*

Surplus Water Works Funds. ANON. W. W. Inf. Exch., Canadian Sec., A.W.W.A. **4:** D: 2: 7 (Mar. '41). Township of Stamford recently sued Public Utility Com. of Township of Stamford (Ont.) to obtain surplus funds, amtg. to $19,940.16, accumulated by water works system. Com. had refused to pay surplus to Township, stating that it was being reserved for installation of meters. Judgment delivered Jan. 10, '41, given in full. Public Utilities Act, under which Com. created, states that revenues, after providing for expenses and maintenance of works, shall be paid to munic. to be applied annually to reduction of rates, etc. Further states that such funds shall be credited to acct. of public utility work and if not required for work shall form part of funds of corp. Judgement ruled that expenditure of surplus for installation of meters beyond power and competence of Com. without plaintiffs' consent and ordered that surplus, less working capital of $4,000, be paid to plaintiffs. —*R. E. Thompson.*

RATES

Accounting Aspects of Rate Analysis Technique. F. A. NEWTON. Edison Elec. Inst. Bul. **8:** 558 (Dec. '40). Allowance for accrued depn. dependent upon so many factors and influences, and subject to such changes as operating conditions change, that its detn. is question for managerial judgment. Many have wanted original cost set up as sole basis for detn. of value for rate making purposes, believing it less than cost of reproduction of properties and business of utility. Original cost as existing today not measured by original cost of physical property. In addition there is real cost of obtaining business. Utilities of today are, in many cases, results of mergers with attendant expense, revision of records and methods, and rebuilding of distr. systems. Unification costs must be determined. To date, highest courts have stated that value for rate making purposes is value at time inquiry is made with respect to rates. Despite all arguments about cost of reproduction, original cost, depn., prudent investment and other theories and elements of valuation, if utility industry is to live and grow it will be because it will continue to furnish good service at fair and reasonable rates. Will consistently strive to broaden and increase its market, improve and extend its service and, with full realization of fact that road to still lower rates and better public relations lies through sound rate policies, avoid unjust discrimination, increase sales and efficiency, and lower unit costs. Must, however, resist,

to utmost, unjust attacks and unsound regulatory policies. Installation of uniform rate system either means loss in revenue or increases in bills of large number of customers. Changing of rates, when under jurisdiction of regulatory bodies, takes time. Rates on additional or increment cost basis are sometimes of advantage to both seller and buyer, but may result in reaction. While operating expenses are function of increment costs, additional investments are also required by additional business secured. Customers must be classified and accuracy sacrificed to convenience of classification. Public policy has dictated distance from source to consumer not necessarily rate factor. Great variation of quantity of product consumed in commercial field. Accountants responsible for proper set up and presentation of rate cases.—*Samuel A. Evans.*

How Much Should a Utility Company Be Allowed to Earn? HARRY BOOTH. Pub. Util. Fort. **26:** 281 (Aug. 29, '40). Notwithstanding amount of controversy over utility rates during recent years, it is paradox that during this very period of agitation number of formal rate cases going through courts has shown downward trend. But if quantity of rate litigation has decreased, quality has shown opposite tendency. In other words, while fewer cases going up to U. S. Supreme Ct., resulting decisions are proportionately of greater weight. Supreme Ct. sustained Ill. Supreme Ct., holding: (1) right of a utility to institute an injunction suit in an equity court; (2) commission favored, court followed commission's findings rather than lower court; (3) in determining rate base, commission accorded appropriate weight to original and reproduction costs, then made deduction for depn., recognizing that depn. is fact regardless of new cost basis; (4) commission upheld in disallowing a number of items as improper and unnecessary expenses. Most important is court's statement that a 5% return is non-confiscatory. Tendency of commissions and courts towards decreasing return rates, seldom exceeding 6%.—*Samuel A. Evans.*

Water Service Outside the City Limits. K. F. HOEFLE. Tex. W. W. Short School. **22:** 40 ('40). Dallas, Tex., furnishes water to consumers outside of city through incorporated fresh-water districts as contracted, with renewal and cancellation clauses, and to consumers in non-incorporated districts on same bases as to citizens, but double city rate. Design and control of all extensions under supervision of water dept. because of likelihood that area so served will some day be annexed to city. In case of annexation, entire system becomes property of city. *Discussion.* ALBERT R. DAVIS: Cites 3 kinds of city charters, and rights delegated therein, and emphasizes desirability of consulting and following advice of city attorney. In Austin, Tex., one of contracts provide that mains conform to standard constr. practice of dept., and for purchase of mains if and when annexed to city. Another form of contract requires that entire cost of extension be paid by property owners and that deed of transfer be made to city in return for maintenance and upkeep. Customer in both above cases pays 1½ rate.—*O. M. Smith.*

Water Supplies for Outlying Settlements. REINHARD SCHEMEL. Gas u. Wasserfach. (Ger.) **84:** 81 (Feb. 8, '41). Type of settlement contains 2-family houses, each with considerable ground for vegetable garden. Houses connected to public water supply to get safe water and some fire protection. Sewage used on ground. Settlers have to carry whole cost of water supply, except cost of excess sizes put in for future extensions of settlement. Consumption found to be 5–10 g.p.d. per capita where no bath and water toilets provided, otherwise 18 g.p.d. per capita. Highest daily consumption varies to lowest as 4 to 1 and 3 to 1. Details of arrangements and costs of water supplies of 6 settlements given. Costs for individual house run from 1 to 3% of construction cost of house. Cost of individual wells would be about 1%.—*Max Suter.*

Some Objectionable Features of Sprinkling Rates. L. M. BURNHAM. Southwest W.W.J. **22:** 10: 16 ('41). Sprinkling

rates not only add to, but very often multiply work of billing depts.; discriminate between types of customers as well as between consumers of same classification. Use of rate has tendency to discourage use of water for lawn sprinkling and other uses during off-peak season.—*O. M. Smith.*

The Question of Free Water. ANON. Am. City. **55: 7:** 44 (July '40). For more than 25 yr. Ohio debated question of supplying free water for public and semi-public purposes. In '30, taxpayer of Cleveland requested Law Dept. to restrain Dept. of Pub. Utilities from supplying free water. 7 yr. later case was ordered to trial and in '38 decision was handed down stating that no legal authority existed for water dept. to furnish water at either free or reduced rates to other city depts. or public institutions. Taxpayer promptly enjoined Director of Pub. Util. from longer supplying free water to these institutions and depts. Question of supplying free water to any public or semi-public institution or agency was not settled by first decision and is now being followed up by another taxpayer's suit.—*Arthur P. Miller.*

Water Rates and Water Meters. S. MAHADEVA. Wtr. and Wtr. Eng. (Br.) **42:** 41 (Feb. '40). Right to free supply of water from public source is untenable. Authority responsible for water supply must be reimbursed. Situation is analogous to supply of electricity or gas. Water may be paid for on either *rateable* or *quantity* basis. In former, fixed rate is levied on assessed value of property for cost of water, rate being fixed to cover estimated value of service rendered. Rate is not made an unconscionable source of revenue since water companies are controlled in rate making in India. In Bengal rates vary between 3 and 7½%; in Ceylon between 4 and 6%; and in some of United Provinces, between 5 and 7%. In Great Britain rate depends on rental value of property. On rentable value of £20 rates vary between 6s-8d and 67s-6d. On *quantity* basis consumer pays for what he gets; water being metered. Objection offered to meters is possible restriction to use of water. Meter system in force in most European continental cities. Metering viewed with less favor in England. In Johannesburg, South Africa, rateable basis used and with additional metered charge for water used over fixed max. Usual to allow 2% error in meters moving fast and 3% when moving slow, with not more than 2% in favor of supplier and 3% favoring consumer. Ideal meter should: (1) register accurately from dribble to full bore, under varying pressures, with small friction loss, and (2) should be durable, not easily clogged, should not permit backflow, and should register only when water is passing through it. Water works authority should be equipped to test meters on its distr. system.—*H. E. Babbitt.*

More Water for Revenue. P. A. SHAW. W. W. Eng. **93:** 166 (Feb. 14, '40). Metered water sold to consumers in Manchester, N. H. (pop. 80,000) as measured by consumer meters 75% of that sent to system in '33, had increased to 76.5% in '36 and 87.4% in '38; income has increased from $108 per mil.gal. pumped in '34 to $112 in '37, and $113.70 in '38 with rates remaining practically unchanged. Rates are 10¢ per 100 cu.ft. for first 100,000 cu.ft. in any quarter, 7¢ for next 200,000 cu.ft., and 5¢ for all over 300,000 cu.ft. in any quarter. City a mfg. city on Merrimack R.; water system has 1,041,000′ of pipe of which 28,500′ are 4″ and under, 551,100′ and 6″, 359,800′ from 8″ to 14″, remaining 102,000′, from 16″ to 30″; services number 11,700, all but 100 metered. Ave. of 128 service leaks found annually.—*Martin E. Flentje.*

Ottawa Water Rates Case. ANON. W. W. Inf. Exch., Canadian Sec., A.W.W.A. **4:** D: 1: 1 (Jan. '41). In '40, Ont. Munic. Board Act was amended to give Board authority to deal with rates charged for water supplied by one munic. to another. Subsequently, 4 munics. supplied by Ottawa asked for review of their rates and Ottawa challenged right of Board to fix rates charged to these outside areas. Abstracts of decisions of Board and of Court of Appeal on this question given. Both in agreement that Board was

within its rights to hear such applications and to fix rates, except where a contract was in force. In opinion of Court of Appeal, '40 amendment does not affect rights existing at time of enactment. Only two of municipalities had formal agreements with Ottawa. Rates, therefore, not subject to review by Board, while other two are.—*R. E. Thompson.*

Pennsylvania Public Utility Commission *v.* St. Marys Water Company. Pub. Util. Fort. P.U.R. **36:** 75 (Jan. 16, '41). Commission instigated investigation to determine lawfulness and reasonableness of water company's rates. Water company's estimate of annual depn. erroneous where based on present physical deterioration as it may be affected not only by normal but also by delayed maintenance, together with amt. of abandonments or retirements to which annual depn. of present plant is not related. Company's estimate of accrued depn. shown with respect to physical property only as representing irreparable present physical deterioration plus expenditures necessary to restore 100% efficiency, expanded proportionately to obtain corresponding amt. with respect to all depreciable property, including depreciable overheads, is erroneous. Estimate of 1.87% of fair value of company's property was allowed as annual depn. for rate-making purposes. Company's estimate of cash working capital constituting net balances of cash on hand, accts. receivable and unbilled water service, offset by accts. payable, is irrelevant for rate-making purposes, since it reflects only whatever choice company may have with respect to its cash position, accts. receivable, and accts. payable, without regard to actual requirements. Extraordinary expenses due to flood allowed to be amortized over 10 yr. in fixing rates. Pension expenses required under adopted pension plan through life insurance company for present eligible employees, allowable as operating expenses for rate-making purposes. Pension expenses not incurred under reasonable prearranged and regularly established pension plan not allowable as operating expenses for rate-making purposes. Rate of return of 6% and 1.87% for annual depn. considered as not excessive upon any reasonable determination of fair value which commission would be warranted in finding upon record. One comr. dissenting stated 5% and 1%, respectively, rate base not to exceed original property cost plus stated sum for working capital, materials and supplies.—*Samuel A. Evans.*

Pennsylvania Public Utility Commission *v.* California Water Co. Pub. Util. Fort. P.U.R. **37:** 151 (Apr. 10, '41). Com. findings and rulings. Under provision of Public Utility Law, inquiry and investigation instituted to determine fairness, reasonableness and justness of rates and charges of Calif. Water Co. operating in certain boroughs of Pa. Existing water works and original cost as shown on books given. Bonus payment by a water co. in connection with sale of bonds must be included from original cost. If capital stock issued to party for services rendered, such as purchase, merger, franchise, and then services not useful in furnishing service to public, cost of stock must be deducted from original cost. Cash value of securities issued for eng. services must be deducted from original cost, when services performed not recorded or com. concludes engr. overpaid. If no real property acquired, only franchise, which was not used, purchase price cannot be added to fixed capital for rate-making purposes, and amount is deducted from original cost. Estimated reproduction cost based on previous cost with 15% estimated increase on material and labor basis without probative value for rate-making. Reproduction cost, based on previous priced inventory with later additional costs, acceptable, but, reproduction cost increases between fixed dates, going cost, financing cost and cash working capital excluded. Cash working capital considered as amt. of money required for operation between beginning of service billing period and time when payment received for service. No addition to original cost for financing, when brokerage or other costs applicable to issuance of securities not shown. 2%

allowance for financing costs in reproduction cost estimates, excluding financing and going cost. Allowance for going value must be substantiated by actual lag in earnings in early days of business. Computing of accrued depn. on property of relatively long service life by straight-line method; findings therefrom not conclusive though given weight. Com. recognizes 4% compound interest method in determining annual and accrued depn. Well-established principle that cost of extraordinary maintenance should be amortized over period of probable recurrence. Increases of salaries must be substantiated by duties commensurable thereto. Allowable annual depn. 1.5% on assumed fair value as determined by com. Company's annual operating revenues less than com. allowed for a recent 5-year period.—*Samuel A. Evans.*

Utah Public Service Commission. ***Re Pleasant Green Water Company.*** Pub. Util. Fort. **34:** 80 (Aug. 15, '40). Water co. made application for increased rates based upon proposed construction of a sewer, holding that consumers would install modern plumbing conveniences, resulting in additional use of water, which would, in turn, bring about increased operating costs to the co., and necessitate purchase of new equipment. Com. denied application for increased rates holding that: additional costs are in realm of probability; under law, increase in rates cannot be permitted unless justification is shown therefor; no evidence presented that rate increase is justified; and therefore increase in rates is denied. —*Samuel A. Evans.*

Errata Notice

On pages 968 and 969 of the May JOURNAL there appeared two maps showing the hardnesses of the chief Canadian supplies. Some of the symbols were not reproduced clearly in printing all Journals; therefore it is suggested that readers wishing specific data write the Canadian Bureau of Mines at Ottawa for the maps accompanying the Interim Reports.